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PAPERS AND PROCEEDINGS OF

The Royal Society of Tasmania

Edited by M. R. Banks and S. J. Smith

and Published by the Society

Hobart, Tasmania

August 1983

NATIONAL MUSEUM
-7 DEC 1983
OF VICTORIA

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President

His Excellency the Governor of Tasmania
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succeeded by Sir James Plimsoll

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ROYAL SOCIETY OF TASMANIA

ANNUAL REPORT FOR THE YEAR 1982

The Council has the honour to present to members the following report on the activities of the Society during the year.

COUNCIL AND OFFICE BEARERS

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Mr D.B. Churchill

Honorary Editor
Dr M.R. Banks

Assistant Honorary Editor
Dr S.J. Smith

PRESIDENT

Sir Stanley Burbury took the Chair, as President of the Society at the Annual General Meeting in March. A vote of thanks for his services to the Society was carried by acclamation. A bronze model of *Zygomaturus trilobus* sculptured by Mr H.D. Barker was presented to His Excellency.

The Society was honoured when Sir James Plimsoll accepted the position of President of the Society thus following in the steps of all Governors of Tasmania since Sir John Eardley-Wilmot became the President in 1843.

NATIONAL MUSEUM
-7 DEC 1983
OF VICTORIA

ROYAL SOCIETY OF TASMANIA MEDAL

At the General Meeting in November, the Royal Society of Tasmania Medal was presented to Dr Grote Reber in recognition of prolonged research of high merit.

Previous recipients of the Medal have been:

1927	L. Rodway	1940	W.L. Crowther and V.V. Hickman
1930	C.E. Lord	1970	D.L. Serventy
1934	H.H. Scott	1976	D. Martin
1935	A.N. Lewis	1978	M.R. Banks

ANNUAL MEETING

At the Annual Meeting on 2 March, Mr D.R. Gregg retired as Vice-President and Mr G.E.A. Hale and Mr L.E. Wall as Members of the Council. The following were elected:

Vice President	Mr L.E. Wall
Members of Council	Mr A.V. Brown
	Dr P.W. McCartney
Honorary Secretary	Mr D.R. Gregg
Honorary Treasurer	Mr T.A.H. Knight
Honorary Auditor	Mr D.B. Churchill

REVISION OF RULES

The Rules, as amended at the 1981 Annual General Meeting, were further amended at a Special Meeting held on 7 September, 1982. The revised Rules have been reprinted and are being distributed to Members.

MEMBERSHIP

The membership is 464, a decrease of 6, and is made up as follows:

	Northern Branch	Total
Honorary Life Members	3	7
Life Members	8	35
Ordinary Members receiving the Papers and Proceedings	63	273
Ordinary Members not receiving the Papers and Proceedings	74	132
Associate Members	15	17
	163	464

COUNCIL MEETINGS

The Council met four times during the year with Mr P.G. Webb and Mr R.E. Ward representing the Northern Branch on the Council.

BANKS MEMORIAL LECTURE

The Council has continued to pursue the proposal that the bicentennial of the European settlement of Australia in 1988 be marked by a lecture honouring Sir Joseph Banks.

PUBLICATIONS

Volume 116 of the Papers and Proceedings was published in August 1982. It contained 13 papers by 22 authors and totalled 219 pages. The Society is once more indebted to Dr Banks for his dedicated and expert work as Honorary Editor. Dr S.J. Smith has been appointed Assistant Honorary Editor.

LIBRARY

The Library has continued to function smoothly during the year under the direction of the Librarian, Mrs Mary Marshall, who reports as follows:

The continuing steady use of the Library emphasises its importance as a reference source for Royal Society members, University staff and students and researchers from the community at large. During the year 470 visitors signed the users' Register, and 176 items were lent to other libraries through the University's Interlibrary Loan Service.

The library receives 689 journals currently from its 293 exchange partners, and subscribes to 7 additional titles. During the year exchanges were established with two new partners, the Naturwissenschaftlicher Verein für Steiermark, Graz, Austria for their Mitteilungen, and the Goulandris Natural History Museum, Kifissia, Greece for their Annales Musei Goulandris. In October the Royal Dublin Society, an exchange partner since the 1880's, advised that its exchange of scientific journals would cease at the end of 1982, and its two journals - Journal of Life Sciences and Journal of Earth Sciences - would in future be available on subscription only.

During the year the Library purchased the biography of Baron Sir Ferdinand von Mueller, A MAN ON EDGE by Edward Kynaston, and received the following donations:

Oats, W.N.: BACKHOUSE AND WALKER -A QUAKER VIEW OF THE AUSTRALIAN COLONIES. Blubber Head Press, 1981.

Grundy, J.H.: ARTHROPODS OF MEDICAL IMPORTANCE. ed. N.R.H. Burgess. Noble Books, 1981.

Grundy, J.H.: MEDICAL ZOOLOGY FOR TRAVELLERS. Noble Books, 1979.

Pullman, E.E.F.: THEY CAME FROM THE MALL, BEING AN ACCOUNT OF THE LIVES OF JAMES WENTWORTH AND SOPHIA LETITIA DAVIS. Frankston City Press, 1982.

Following an assessment of the value of much of the Library's monograph collection it was decided at the Council's April meeting that in future the monograph collection be considered a reference collection, loans of one week's duration to be arranged only in special circumstances and at the Librarian's discretion. Bound periodicals continue to be available for one week's loan to Society members, University staff and Higher Degree and Honours students.

The University Bindery continued its excellent binding programme, and 2 330 volumes of Royal Society periodicals were bound during the year. This means that although there are still several thousand volumes waiting binding, most of the very long and higher risk titles have now been bound. Replacement of missing parts has been achieved by purchase from or donation by the exchange partner, or, in the case of out of print issues, by obtaining a photocopy from another library.

Mrs Marshall retired at the end of 1982 and Council has recorded its appreciation of her dedicated service to the Society since her appointment as Librarian in 1980.

LECTURES

The following lectures were given at General Meetings during the year:

March	"Simpkinson de Wesselow - a colonial painter extraordinary."	Mr Max Angus
April	"What are little things made of?"	Professor R. Delbourgo, University of Tasmania
May	"As man sows..."	Dr J. Goldsmid, University of Tasmania
June	"Burning issues - fire ecology and society."	Mr David Brown, University of Tasmania and Mr Tony Mount, Tasmanian Forestry Commission

July	"Aboriginal man and landscape in western Tasmania."	Mr Kevin Kiernan University of Tasmania
August	"Marine geoscience off Antarctica" and "Antarctic Division participation in the first International Biomass Experiment (Fibex) Programme."	Dr P.G. Quilty and Dr H. Marchant, Antarctic Division.
September	"The South Heemskirk Tin Field - sixty years of wasted effort."	Mr L.S. Whitham
October	"The present position and status of the Tasmanian Aborigines."	Dr Lyndall Ryan, Griffith University
November	"Procreation without pleasure."	Professor J.F. Correy University of Tasmania.

NORTHERN BRANCH

Chairman	Mr R.E. Ward
Vice-Chairman	Mr E.H. Fist
Past Chairman	Mr D. Walter
Council Members	Mr J.H. Chambers
	Mr D.G. Hannan
	Mrs G.M. Morris
	Mr A.T. Orr
	Mr B.A. Pike
	Mr T.M. Tatlock-Goodrick
Honorary Secretary	Mr P.G. Webb
Honorary Treasurer	Mr K.E.J. Robinson
Honorary Auditor	Mr J.D.A. Abey
Representatives of Branch on Council	Mr R.E. Ward Mr P.G. Webb

The Branch Council met four times, the principal business being publications, a discussion on membership, and the development of a set of Bylaws for conduct of the Branch. The latter, after being sighted by the Council, have been adopted and came into effect on 1 January 1983.

Ten General and two Special Meetings were held, at which the following lectures were given:

March	"Anachronisms." "Colonial architecture in Tasmania." (Special Meeting, for benefit of Royal Historical Society of Victoria)	Mr D. Walter Dr E.V. Ratcliff
April	"Edith Holmes, the artist."	Mrs Veda Veale
May	"The Byzantine Empire - its history and its contribution to Western civilization."	Mr P.G. Webb
June	"The communications revolution."	Mr John Ford
July	"The nature of scientific change in the natural sciences."	Mr J.H. Chambers
August	"The ceramics collection of the Queen Victoria Museum, Launceston."	Mr C.B. Tassell
September	"Dodging around Gippsland."	Dr Bess Deakin
October	Visit to the Australian Maritime College, Newnham campus, led by	Mr P. McGovern
	"The present position and status of the Tasmanian Aborigines." (Special Meeting)	Dr Lyndall Ryan

November	"Recollections and reminiscences."	Mr Martyn Croft
December	Members' Night:	
	"The expansion of the Tasmanian Museum."	Mr D.R. Gregg
	"Rhinoceros unicorn."	Mr D. Walter
	"Ecumenism then and now."	Mrs P. Ratcliff
	"Tourism in New Zealand."	Mr G.H. Stancombe

With the approval of Council, the Branch undertook the publication of AUGURIES OF INNOCENCE, a small book containing the addresses given in November 1980, on the occasion of the presentation to the Queen Victoria Museum, Launceston, of Margaret Stone's botanical watercolours for THE ENDEMIC FLORA OF TASMANIA. The main address given by Sir Clive Fitts, was a tribute to the late Lord Talbot de Malahide, who was a member of the Society. Copies are available for sale at $2.00 each.

The Branch also issued a quarterly Newsletter, and printed the following lectures:

"Protection from floods - the Launceston story."	Mr G. Burrows
"The Byzantine Empire, its history and its contribution to Western Civilization."	Mr P.G. Webb
"The nature of scientific change in the natural sciences."	Mr J.H. Chambers
"The present position and status of the Tasmanian Aborigines."	Dr Lyndall Ryan

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31 DECEMBER 1982
NORTHERN BRANCH

(1981)					(1981)
169.65	Balance brought forward	1 050.22	Subscriptions to Hobart	84.00	45.00
45.00	Subscriptions (a/c Hobart)	84.00	Printing and stationery	635.70	130.99
83.40	Sale of publications	122.17	Theatre hire	90.00	74.00
19.40	Suppers	21.54	Suppers	14.29	20.93
	Dinner (farewell Sir Stanley Burbury)	200.00	Postage	196.18	92.21
24.62	Bank interest	37.74	Post Office box	18.00	16.00
1 100.00	Grant - Royal Society, Hobart	700.00	Telephone and petty cash	10.15	5.22
	Postage	3.47	Attendance Council meetings	89.70	
			Dinner (farewell Sir Stanley Burbury)	340.00	
			Stamp Duty bank book	7.50	4.00
			Lectures	40.80	
			Delivery of Papers and Proceedings		3.50
			Bank balance	692.82	1 050.22
$1 442,07		$2 219.14		$2 219.14	$1 442.07

NOMINEES TO OTHER BODIES

The Council re-elected Dr M.R. Banks and Mr A.R. Neilson to the Board of Trustees of the Tasmanian Museum and Art Gallery. They report on the year's activities:

The Trustees continue to be seriously disturbed at the level of financial support from the Tasmanian Government. The State Government grant for 1982-83 was $770 000. This was an increase of 10% on the 1981-82 grant but still below the expected rate of inflation. Over 86% of this grant has been allocated to cover salaries and related costs. The Trustees, have, however, decided not to retrench staff this financial year. They have considered it impossible to make any allocation from the Government grant to cover purchases for the collections or towards costs of exhibitions.

This decision will almost certainly mean that the people of Tasmania will not have the opportunity of seeing the wide variety of high quality touring exhibitions shown in recent years. The availability of future exhibitions will depend on attracting commercial sponsors.

The decision not to allocate any State Government funds for purchases for the collections, may mean that items of importance to the heritage of Tasmania will not be able to be acquired for the enjoyment and education of present and future generations of Tasmanians.

In 1981, the acquisition of a Tasmanian sketch-book by John Glover (1767-1849) was an event of national significance. The purchase of the sketch-book was made possible only through grants made by the Hobart City Council.

Lack of funding has also prevented any resumption of work on the renovation of the Commissariat Store buildings at 40 Macquarie Street. Work stopped on this partly completed project in August 1980. The completion of the renovation is urgently required to provide adequate working space and storage for the history and anthropology departments.

Non-government organisations in Tasmania have provided assistance: the Tasmanian Teachers Credit Union has promised funds of up to $14 000 towards a new numismatic display, the Electrolytic Zinc Company has helped with the purchase of books on lichens for the library of the Herbarium, Davies Bros. sponsored the Tasmanian visit of the very successful exhibition of watercolours from the Fitzwilliam Museum, Cambridge, England, and Renison Ltd presented a very valuable collection of minerals for display at the West Coast Pioneers' Memorial Museum, Zeehan.

The establishment of the Friends of the Tasmanian Museum and Art Gallery has lead to an increased involvement of the community. There are now 285 members both family and individual involving an estimated 600 people.

During 1982 visitors to the Tasmanian Museum and Art Gallery totalled 102 251, compared with 120 537 for 1981. The attendance at the West Coast Pioneers' Memorial Museum at Zeehan was estimated at 132 000 for the 1981-82 financial year.

Dr Banks was re-elected Chairman of Trustees.

Dr Jocelyn E.S. Townrow continued as the Council's nominee on the Board of Trustees of the Royal Tasmanian Botanical Gardens. She reports on the year's activities:

The Gardens have been well maintained in spite of severe water restrictions imposed during the past difficult year. The conservatory with its summer display, the best for many years, was one of the most popular features. The total number of visitors was in excess of 204 500, much the same as last year despite drought and recession.

Messrs May (Superintendent), Gray (Information and Education Officer) and Dr Vitesnik (Landscape Designer) are to be complimented on their high standard of service and dedication. The staff compliment of 30, already 5 short, fell to 25 during April and May with 2 short in the labour-intensive nursery, in accord with Government policy regarding non-replacement of staff in Government instrumentalities.

State Government funding increased to $685 000 in keeping with the inflation rate, and $466 390 of this sum was for wages and salaries, leaving $218 610 for up-keep of the Gardens and Museum. Again, because of financial stringency it has not been possible to replace the derelict depot area and No.4 glasshouse.

The Museum and Education Office has attracted about 12% of those visiting the Gardens (compared with about 9% last year) even though it has restricted opening hours to 11 am-1 pm and 2 pm-4 pm. This increase reflects the interest generated by new displays designed and implemented by Mr Gray. About 21 100 visitors have examined the displays of live ferns and water plants in the Botany room, the newly furnished History room featuring photographs and biographical notes of Tasmanian botanists with a central "free-standing" cabinet of living native plants named in their honour, the expanded Economic plants room with its display of grasses, tropical crops and essential oil plants, and the live beehive and silkworm section. A recent acquisition in the Board Room of 7 large wall charts displaying pressed native plants of S.W. Tasmania has stimulated much favourable comment. These were prepared and donated by Mesdames M. Johnstone and P. Hamilton, the wives of two National Parks and Wildlife Service rangers at Strathgordon. The Friends

of the Gardens, now some 40 in number, contributed greatly not only to the safe-keeping of the Museum, but also in answering visitors' questions. Mr Gray gave talks and conducted tours for about 3 800 school children on 102 school visits to the Gardens, and for 135 adults during his first, highly successful year of office. He also conducted a seminar for 25 teachers in Rural Science Studies.

The major part of the Easy Access Garden was officially opened after the completion in May, and the final finishing touches to the toilet facilities were in hand by mid-December. Fund raising for the glasshouse to complete the project received a boost of $3 000 from a further plant sale run by the Superintendent and staff volunteers. Handicapped Persons Services have promised funding for a part-time handicapped person to be in charge of the Easy Access Garden for 8 hours per week for 6 months starting early in 1983.

A Government grant has enabled commencement of the first phase of reconstruction of the Gardens sewerage system. This will include installation of a pumping station and rising main to connect with the Hobart City Council's sewerage main at Cornelian Bay.

Thanks to a further grant of $10 000 from the National Estate in December, final work is proceeding in restoration of the historic Eardley Wilmot Wall.

The Year of the Tree was celebrated in the Gardens when over 2 500 plants were given away to the public and 80 trees were planted in the northern end of the Gardens by various Clubs, Brownies, past and present Trustees, the Minister for the Environment, the Lord Mayor and the Chairman of the Year of the Tree Committee. A schools poster competition run by the Superintendent attracted over 100 entries with prizes of $100 worth of plants.

Following liaison with the Tasmanian Aboriginal Centre in Hobart, consideration of the development of the Aboriginal Midden Site at the northern end of the Gardens as an Education display feature, has been postponed. It is hoped that a joint venture can be successfully developed in due course.

The design of the "Wombat One Shelter" was recognised by the Royal Australian Institute of Architects with the award of its Triennial Award of Merit for 1982.

The most outstanding of several new features designed and implemented by Dr Vitesnik is the traditional style raised herb garden situated next to the historic Arthur Wall which will display plants used in medicine, cooking, dyeing and perfumery.

Several outside displays have been provided by the Gardens staff, the most successful being that of Culinary and Medicinal Herbs which gained a Certificate of Merit at the Royal Hobart Show.

At its final meeting for the year the Board of Trustees expressed appreciation to Professor Jackson for his 21 years of service as the Trustee representing the University of Tasmania.

ACKNOWLEDGEMENTS

The Council is grateful for help generously given by many individuals and organisations. In particular, the lecturers, the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery, and the Queen Victoria Museum and Art Gallery are specially thanked for their help and cooperation.

ROYAL SOCIETY OF TASMANIA

AUDITED BALANCE SHEET AS AT 31 DECEMBER 1982

1981			1982	1981		1982
49 439.48	Accumulated funds		56 164.83	33.00	Cash on hand	33.00
49.00	Subscriptions in advance		88.00		Cash at bank:	
	Trust funds:			4 727.80	- General Account	2 666.53
1 429.68	- Clive Lord Memorial Fund	1 568.15		4 101.02	- Papers & Proceedings Account	520.51
2 353.14	- A.N. Lewis Memorial Fund	2 605.38		773.49	- Clive Lord Memorial Fund	160.09
1 053.42	- Morton Allport Memorial	1 163.56		1 318.78	- A.N. Lewis Memorial Fund	244.51
438.73	- A.A. Clark Bequest	477.36		860.00	Mortgage Loan	860.00
2 933.52	- Joseph Milligan Bequest	3 210.99			Commonwealth Treasury Bonds	
1 544.59	- R.M. Johnston Memorial Fund	1 714.51		14 440.00	& Inscribed Stock (at cost)	29 900.00
683.26	- Henry Oliver Bequest	754.53		7 000.00	Interest Bearing Deposits	7 000.00
1 581.07	- W.H. Hudspeth Memorial	1 733.16		15 000.00	Library (at valuation for insurance)	15 000.00
2 413.55	- Life Membership Fund	2 645.07		15 665.35	Publications (at selling prices)	15 740.90
			15 872.71			
$63 919.44			$72 125.54	$63 919.44		$72 125.54

ROYAL SOCIETY OF TASMANIA

STATEMENTS OF RECEIPTS AND PAYMENTS
FOR THE YEAR ENDED 31 DECEMBER 1982

GENERAL ACCOUNT

Balance brought forward		4 727.80	Stationery	289.24
			Insurance	145.70
Subscriptions			Attendant's fees	508.01
263 @ $12	3 154.00		Secretarial fees	1 262.25
131 @ $8	1 048.00		Lecture expenses	181.60
19 @ $5	94.00		Post box rental	88.00
Other years	148.00		Postage and freight	986.55
			Investments	9 560.00
			Photocopying	33.95
		4 444.00	Subscriptions	701.74
			Northern Branch	700.00
Interest		3 466.89	Repairs and maintenance	545.88
Rent		294.59	Stamp duty	18.30
Miscellaneous, including printing refund		1 057.45	Miscellaneous	19.65
Donation		15.00	Typing of Papers and Proceedings	2 281.90
Sales of publications and Papers and Proceedings		2 138.57		17 322.77
University subvention		3 845.00	Balance carried forward	2 666.53
		$19 989.30		$19 989.30

PAPERS AND PROCEEDINGS ACCOUNT

Balance brought forward	4 101.02	Investments	4 000.00
Interest	426.99	Stamp duty	7.50
		Balance carried forward	520.51
	$4 528.01		$4 528.01

ACCUMULATION ACCOUNT

Balance 1 January 1982			49 439.48
Deduct: Net transfers to Trust Funds	1 441.75		
Net increase in advance subscriptions	39.00		
Decreased cash at bank	7 329.45		
			8 810.20
			40 629.28
Add: Net increase in valuation of publications for sale	75.00		
Increased investments at cost	15 460.00		
			15 535.55
Balance 31 December 1982			$56 164.83

Papers and Proceedings of the Royal Society of Tasmania, Volume, 117, 1983.

(ms. received 18.6.1982)

LIVER FLUKE INFECTION IN NORTHWESTERN TASMANIA

by David Obendorf and Tom Black
Tasmanian Department of Agriculture,
Mt. Pleasant Laboratories,
Launceston South, Tasmania.

ABSTRACT

OBENDORF, D. & BLACK, T., 1983 (31 viii): Liver fluke infection in northwestern Tasmania. *Pap. Proc. R. Soc. Tasm.*, 117: 1-3. ISSN 0080-4703. Tasmanian Department of Agriculture, Mt Pleasant Laboratories, Launceston South, Tasmania.

In 1979, liver fluke, *Fasciola hepatica* was reported in home-bred cattle, grazing coastal country at Mt Cameron West. Subsequent investigations confirmed the presence of the obligate intermediate host snail, *Austropeplea tomentosa*, in the draining water system and the presence of liver fluke in the herbivorous macropod, *Thylogale billardierii*. The infection, the first recorded in northwestern Tasmania, further supports observations that marsupials may act as reservoirs of liver fluke.

INTRODUCTION

Fasciola hepatica is a common and widespread parasite of the temperate wet agricultural areas of southeastern Australia, wherever the habitat is suitable for the snail intermediate host, *Austropeplea tomentosa* (Boray 1969). In Tasmania, *Austropeplea tomentosa* represents the sole intermediate host for liver fluke. This freshwater snail is widely distributed in the river systems of the North and South Esk, in the central highlands, the Derwent Valley and the rivers draining into the east coast (Boray 1964). It is considered to be an endemic Tasmanian snail (Kershaw, pers. comm.). Liver fluke is reported in all these abovementioned agricultural areas. Significantly, infection is not known from the farm lands of northwestern Tasmanian (west of Devonport) or King Island.

From distribution studies of *Austropeplea tomentosa* collated by Boray (1964) and Smith and Kershaw (1980), the snail has been reported from locations not included in the recognised enzootic fluke areas. These include reports from the Stanley municipality and King Island (Petterd 1889). In addition, *A. tomentosa* (syn. *Amphipeplea launcestonensis*) is reported in fossil deposits from the Mowbray Swamp, near Smithton (Gill and Banks 1956).

This paper records the occurrence of *A. tomentosa* at a location in northwestern Tasmania and reports the existence of liver fluke infection in both cattle and a species of macropodid marsupial. The origin and maintainance of liver fluke at this site is also discussed.

RESULTS AND DISCUSSION

Until recently, fascioliasis was not thought to occur in northwestern Tasmania. In 1979, an 80% prevalence of liver fluke was recorded in young home-bred cattle which had grazed the coastal heath country at Mt Cameron West (lat. 40°52'S, long. 144°43'E). Records of the pastoral company which uses this country show that sheep, the main definitive host for liver fluke, grazed the area 18 to 20 years ago. These sheep were brought at sale and the possibility exists that they may have been infected with liver fluke.

During the spring of 1981, searches of the freshwater soaks and pondages in the heathlands behind the established dune of the Mt Cameron area, confirmed the presence of large numbers of *Austropeplea tomentosa*. Squash preparations of several gastropods and internal organs of the snail revealed numerous cercarial stages in each snail.

Although it is well known that cattle may harbour liver fluke, they are considered secondary or even aberrant hosts (Jubb and Kennedy 1970; Blood *et al.* 1980). The host inflammatory response to migrating immature fluke and to adults in the bile ducts is

severe (Jubb and Kennedy 1970). These factors combined with the strong degree of resistance to re-infection suggests that the contribution of cattle to pasture contamination is poor.

The presence of an infected, breeding population of lymneiid snails coupled with the long absence of the preferred definitive host, the sheep, suggested that marsupial herbivores may be of importance in the maintenance of the infectivity of the area for cattle. Unfortunately, there was no opportunity to assess the fluke egg contamination caused by the infected cattle. Most of the cattle were slaughtered. The acquisition of the area by the Tasmanian Government for an aboriginal relics reserve has also prevented any future investigations of the cattle infection.

The susceptibility of marsupial herbivores to liver fluke infection is well recognized (McManus 1979; Spratt and Presidente 1981). In Tasmania, liver fluke infection is reported in the forester, *Macropus giganteus tasmaniensis*, Bennett's wallaby, *M. rufogriseus*, the red-bellied pademelon, *Thylogale billardierii*, the common wombat, *Vombatus ursinus*, and the brush-tailed possum, *Trichosurus vulpecula* (McManus 1979). It is generally accepted that the parasite has been introduced with domestic herbivores, particularly sheep. Marsupial infection has occurred as a result of grazing environments becoming contaminated by livestock and made infective by transmission through the intermediate host snail.

In November 1981, seven red-bellied pademelons were shot at Mt Cameron West. This species was judged to be the predominant macropod in the area. Two were infected with *F. hepatica*. Mature egg-producing fluke were recovered from both livers. Both infected livers were severely distorted with extensive fibrosis and typical cystic bile ducts. Both infected pademelons were passing liver fluke ova in their faeces, the more heavily parasitised animal at a rate of 70 eggs per gram of faeces.

Taking into account the collection time (November) and the absence of migration tracts caused by immature fluke in the livers of some juvenile pademelons, the infection was probably acquired in previous autumn and winter periods.

It is known that both Bennett's wallabies and red-necked pademelons may harbour up to 80 mature flukes and pass up to 900 fluke eggs per gram of faeces. At this heavy infection rate however, winter mortality would be expected (Presidente, pers. comm.). Lighter infections may well be tolerated with limited impairment to the host and thereby represent a continuous contamination threat.

The liver fluke occurrence at Mt Cameron West may have represented a situation where macropods acted as the predominant host for liver fluke and the source of infection for cattle, after the sheep were removed. Preliminary investigations suggest that this location represents an isolated focus of liver fluke. The water system is a closed one draining the surrounding wooded dunes and flowing into the sea.

The suggestion that macropods act as reservoirs of liver fluke has been stated previously (McManus 1979). Such fluke infections in macropods may represent a significant problem in the control of liver fluke in domestic livestock. A similar situation at Tidbinbilla Nature Reserve has been reported (Spratt and Presidente 1978). At that particular locality, liver fluke is maintained by the eastern grey kangaroo, *Macropus giganteus*, in the absence of domestic animal hosts.

ACKNOWLEDGEMENTS

The authors wish to thank Dr Brian Smith, National Museum of Victoria for identifying the snails collected at Mt Cameron West and Mr Ron Kershaw, Honorary Associate of the National Museum of Victoria, for information on the distribution of *Austropeplea tomentosa* in northwestern Tasmania. The assistance of the National Parks and Wildlife Service is also gratefully acknowledged.

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POSTSCRIPT

Since this article was written another site of liver fluke infection has been investigated at Sandy Cape (lat 41°25'S, long. 144°45'E). *A. tomentosa* containing developing stages of *F. hepatica* were found in two water systems with similar aquatic habitats to those at Mt Cameron West. The macropodid species, *M. r. rufogriseus* and *T. billardierii* were found to harbour fluke infections at Sandy Cape. Introduction of liver fluke by domestic herbivores is again possible since this coastal area is used for livestock agistment.

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CONSERVATION OF TASMANIAN MACROPHYTIC WETLAND VEGETATION

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(with three tables and one text-figure)

ABSTRACT

KIRKPATRICK, J.B. & HARWOOD, C.E., 1983 (31 viii): Conservation of Tasmanian macrophytic wetland vegetation. *Pap. Proc. R. Soc. Tasm.*, 117: 5-20. ISSN 0080-4703. Department of Geography, University of Tasmania, Hobart, Tasmania, Australia, and Department of Minerals and Energy, Konedobu, Papua-New Guinea.

Approximately 200 macrophytic species, of which thirty-one were poorly reserved or unreserved, were recorded from 530 Tasmanian wetlands. An iterative strategy locates six wetlands within which sixteen of these species occur, individual wetlands being suggested to provide a minimum level of reservation for the remaining species. Half of the major wetland plant communities, as defined by dominant lifeform and species, are unreserved, and a further quarter are poorly reserved.

INTRODUCTION

The conservation status of Australian wetlands has attracted considerable interest in recent years (e.g. Gooderick 1970, Jones 1978). The main focus of much of the work on Australian wetlands and their conservation has been on the avifauna, although Tyler (1976) discussed the conservation status of the interesting vegetation at the Lagoon of Islands and there is a recent review of Australian wetland vegetation (Briggs 1981). This paper documents the results of an investigation into the conservation of Tasmanian wetland species and plant communities. A later paper will discuss the synecology of the major Tasmanian wetland plant communities.

METHODS

Wetlands were defined as vegetated or temporarily unvegetated areas covered by non-tidal, still water less than 4 m deep for several months of the year or more. This definition excludes salt marshes, the subject of a previous study of wetland conservation in Tasmania (Kirkpatrick & Glasby 1981). Artificial impoundments and wetlands smaller than 0.5 ha were excluded from the study. Most wetlands below 500 m above sea level were included as was a sample of highland wetlands. Few wetlands were visited in the southwest of the state where accessibility is poor.

The following data relevant to this study were recorded from 530 wetlands:
1) The projective canopy coverage class of the tallest stratum in each perceived plant community (0-10%, 10-30%, 30-70% and 70-100%). These were discriminated on the basis of differences in dominance. The lifeforms used were: tree, shrub, grass (Poaceae), sedge (Cyperaceae), rush (Restionaceae, Juncaceae), herb (non-graminoid, non-woody, non-aquatic), aquatic.
2) The percentage of the area of the wetland covered by each zone. Five classes were used: 0-5%, 5-25%, 25-50%, 50-75% and 75-100%.
3) The percentage cover of each observed macrophytic species, bare ground and water in each zone. The classes in 2) above were used.

The wetland survey data and reliable literature reports were used to discover which species were not known from State Reserves (subsequently referred to as "unreserved"). A check of the specimens in the Tasmanian Herbarium (HO) was then made for these latter species in order to gain information on their range outside wetlands and any possible occurrences in State Reserves. The distributions of the remaining "unreserved" species

were mapped and each wetland was given a score which equalled the number of "unreserved" species recorded from it from all data sources. The wetland with the highest score was then designated the first priority for reservation and/or protection of species. The scores were then recalculated omitting the species found in the first priority wetland. This procedure was repeated until all "unreserved" species were in a wetland designated for reservation and/or protection. Where two or more wetlands had the same score the wetland most feasibly reserved or protected was selected. This procedure, described more fully elsewhere (Kirkpatrick 1983), objectively locates the minimum number of wetlands necessary to ensure that each wetland plant species has at least one population in a safe area in Tasmania.

Most wetlands could only be visited once, which meant that certain species had to be identified from limited reproductive material or from vegetative material only. Where possible, vegetative samples were taken and propagated when identification was in doubt. The difficulties encountered in differentiating between closely related species from often inadequate material made it impossible to consistently differentiate between *Scirpus fluitans* and *S. productus*, most *Rumex* species, *Potamogeton australiensis* and *P. tricarinatus*, *Myriophyllum elatinoides* and *M. propinquum* (wetlands 1-99 only), *Ranunculus* species, *Typha* species and native *Agrostis* species.

The plant community is an imprecise entity. Communities with the same dominant species may differ widely in terms of subordinate species, physical and chemical parameters, and productivity. Nevertheless, as the assemblages and relative abundance of plant species form an integral part of the components of the ecosystem, they are one of the best indices for general conservation purposes.

For the assessment of conservation status the wetland plant communities are placed into one of herbfield, sedgeland, rushland, heath, scrub, forest and aquatic vegetation and are defined by the single species with the greatest cover in the tallest stratum.

Within wetlands, communities judged to be less than 0.2 ha in extent were excluded. Thus it can be seen that many smaller areas of a community may have been excluded from the analysis. However most of the area of a community is contained within its larger occurrences, just as most of the area of wetland in Tasmania is located in the upper 50% of the size range. It should also be noted that for many management objectives, such as providing feeding or breeding grounds for many of the larger vertebrates, only large areas of a community warrant consideration.

The percentage of the total surveyed area of each community found within the State Reserve system was then calculated. For the unreserved and poorly reserved communities, wetlands outside the State Reserve system, but preferably within Lands Department Reserves, Wildlife Sanctuaries, Conservation Areas or Crown Land were selected to bring potential reservation of surveyed wetlands up to 5%.

RESULTS

Conservation of the wetland plant species

The vascular plant species observed in the wetlands included in this study are listed in the appendix which also indicates the State Reserves within which particular species are found, shows whether they occur only marginally in wetlands and denotes whether species are Tasmanian endemics, native to Tasmania or introduced to Tasmania.

Most of the native wetland species occur widely on the mainland of Australia. Seven species are Tasmanian endemics. *Centrolepis pulvinata* is reserved only in the Mt William National Park, while the other endemic species are known to have substantial populations in two or more State Reserves. Of the non-endemic native wetland species 30 are not known from any State Reserve.

Sixteen of the thirty-one unreserved and poorly reserved native species could be reserved in six wetlands (table 1). Most of the remaining species are present in reserves

of less secure status than those fully controlled by the Tasmanian National Parks and Wildlife Service, although several species could only be reserved, with present information, by the resumption of privately-owned wetlands (table 1). *Cyperus lucidus*, *C. tenellus*, *Juncus amabilis*, *J. astreptus* and *J. subsecundus* all occur widely outside wetlands in disturbed habitats. Thus, no reservation appears to be necessary.

TABLE 1

DETAILS OF RESERVATION PROPOSALS FOR SPECIES CONSERVATION.

Wetland Code Number	1:100 000 Map	Grid Reference	Species	Land tenure
519	8416	800728	*Centipeda minima, Lythrum salicaria, Polygonum strigosum, Villarsia exaltata*	private
330	8517	156343	*Centrolepis pulvinata, Myriophyllum muelleri, Scirpus pungens, Wilsonia rotundifolia*	Crown land
212	8515	094220	*Baumea articulata, Amphibromus archeri*	private and Crown land reserve
536	8416	520750	*Scirpus caldwellii, S. validus (S. pungens)*	Crown land
272	8515	885900	*Haloragis heterophylla, Juncus revolutus*	Crown land
17	8313	310160	*Juncus vaginatus, Glyceria australis*	Council Wildlife Sanctuary
230	8412	770780	*Juncus squarrosus*	private wildlife sanctuary
530	8416	552710	*Potamogeton pectinatus*	Crown land reserve
344	8517	222228	*Aphelia* sp.	Crown land
707	8313	130340	*Amphibromus neesii*	Crown land and private
444	8000	312939	*Lepilaena bilocularis*	private
88	8311	402370	*Lepilaena preissii*	Crown land reserve
16	8313	300020	*Rumex bidens*	private
297	8517	028662	*Scaevola albida*	Crown land
305	8517	010485	*Wolffia* sp.	private
402	8000	369609	*Polygonum plebeium*	Crown land and private

The native species that are unreserved in Tasmania might be reserved elsewhere in Australia or overseas. None is listed in Leigh, Briggs and Hartley (1981) as threatened or rare. Nevertheless it may be desirable to reserve these species in Tasmania to help avoid local extinction of species or genotypes. To the extent that species reflect habitats, the reservations suggested in table 1 would present the most efficient manner of extending the wetland environments included within the State Reserve system.

The Conservation of Macrophytic Plant Communities

The area of wetland included in the survey was 11 700 ha. Excluding the oligotrophic wetlands in the glacially eroded part of the state, another 2 000 ha of wetland were not included in the survey and approximately 35% (7 000 ha) of the original area of wetland has been drained. Only 643 ha (5.5% of surveyed wetlands) are in State Reserves. Of the wetland vegetation formations only forest and scrub have greater than 5% of their surveyed area reserved (table 2), and these formations had previously been drastically reduced in area as a result of land clearance for agriculture. Sedgeland almost attains a desirable minimum percentage of reservation. Aquatic, herbfield, rushland and grassland are all inadequately reserved (table 2). At the level of communities defined by dominance and structure, reservation is extremely poor. Half the communities occupying more than 10 ha in total are totally unreserved, and less than half of the remaining communities of this extent are adequately reserved (table 3).

TABLE 2

THE RESERVATION STATUS OF THE MAJOR WETLAND VEGETATION FORMATIONS.

	Cover classes (%)				Total	Area Reserved	Reserved (% of area surveyed)
	70-100	30-70	10-30	0-10			
Forest	1040				1040	100	9.6
Scrub	664	13	39	15	731	173.5	23.7
Grassland	70.5	8	5	1.5	85	0	0
Herbfield	103	131	156.5	256.5	647	7.5	1.2
Rushland	133	76	17	4	230	1.5	0.7
Sedgeland	1398.5	2606	770	50	4824.5	220.5	4.6
Aquatic	702.5	1561	810.5	1075	4149	140.5	3.4
TOTAL					11706.5	643.5	5.5

The wetlands recommended as having a high priority for future reservation for community conservation include many of those important for species conservation, and are concentrated in the Furneaux Group and the northeast with a scattering elsewhere in the state (table 3, fig. 1). The selective process ensured that most of these wetland were on Crown land or private land dedicated to nature conservation (table 3).

DISCUSSION

The preceding analysis and discussion somewhat begs the question of the ideal proportion of reservation for wetland plant species and communities. We have assumed that endemic species might be rendered secure with two populations in reserves, that other native species, apart from the most highly opportunistic, might be secured with populations in one reserved wetland, and that communities might require 5% of their present recorded area for security. Most species and communities would be reserved at greater than this minimal level if our reservation recommendations were implemented. With the present state of knowledge on the ecology of wetland macrophytes there is no means of establishing appropriate reservation levels, which would almost certainly differ among the species and communities. The minimal levels effectively assume that wetlands will be constant through time in their species and community composition.

This assumption may be invalid as many wetland environments are highly unstable, particularly in respect to the period of inundation. This instability is very likely necessary for the regeneration and/or maintenance of many of the wetland species and communities (e.g. regeneration of *Melaleuca* scrublands in deep aquatic zones is believed to require exceptionally dry periods). Suitable environments for the growth of particular species disappear for protracted periods or shift drastically within a wetland (Millar 1973). These habitat disappearances are countered in most species by the ability to remain dormant in underground organs or seed until suitable conditions for re-establishment or

TABLE 3

PLANT COMMUNITIES RECORDED FROM MORE THAN 10 HA, with reservation recommendations for those having less than 5% of their surveyed area in the State Reserve system.

Community	Surveyed area (ha)	% reservation of surveyed area	Recommended reservation Code & grid reference			Land ownership
FOREST						
Acacia melanoxylon	1040	9.6				
SCRUB						
Melaleuca ericifolia	664	22.6				
M. squarrosa	33	71.2				
Leptospermum lanigerum	34	0.0	well-reserved outside surveyed wetlands			
GRASSLAND						
Phragmites australis	50	0.0	35	(Derwent River Wildlife Sanctuary)		Crown land
HERBFIELD						
Centella cordifolia	18	2.7	193	078538	8514	private
Lilaeopsis brownii	15	0.0	530	552710	8416	Crown land reserve
Mimulus repens	15	0.0	508	820854	8416	private wildlife sanctuary
Pratia platycalyx	10	0.0	348	155178	8517	Crown land
Sarcocornia quinqueflora	13	0.0	well-reserved in tidal salt marsh			
Selliera radicans	152	0.3	303	100520	8517	Wildlife Sanctuary
						Crown land
			538	560785	8416	Crown land reserve
			330	156343	8517	Crown land
			195	073422	8513	Crown land
Wilsonia backhousei	211	0.0	284	075710	8517	Crown land
W. rotundifolia	122	0.0	286	042743	8518	Crown land
			511	811879	8416	private wildlife sanctuary
			515	812870	8416	private wildlife sanctuary
RUSHLAND						
Juncus kraussii	212	0.7	well-reserved in tidal salt marsh			
SEDGELAND						
Baumea arthrophylla	2518	6.5	-			
B. juncea	63	41.3	-			
Carex gaudichaudiana	85	0.0	well-reserved outside surveyed wetlands			
Chorizandra cymbaria	96	0.0	708	115355	8313	Crown land
Eleocharis acuta	54	0.0	423	385100	8000	private
			717	853405	8213	private
E. sphacelata	185	6.8	-			
Gahnia filum	45	0.0	510	795888	8416	private wildlife sanctuary
G. trifida	203	0.0	273	880890	8518	Crown land
Lepidosperma longitudinale	1072	0.9	16	300020	8313	private
Schoenus tesquorum	77	1.3	717	853405	8213	private
Scirpus caldwellii	100	0.0	97	400375	8313	private wildlife sanctuary
S. cernuus	20	0.0	271	870920	8518	Crown land
S. fluitans	214	0.0	708	115355	8313	Crown land
AQUATIC						
Chara spp.	14	0.0	722	603607	8214	Crown land reserve
Lamprothamnium spp.	1255	0.0	303	100520	8517	Crown land Wildlife Sanctuary
			717	853405	8213	private
Lepilaena cylindrocarpa	151	0.0	330	156343	8517	Crown land
L. bilocularis	11	0.0	444	312939	8000	private
Mimulus repens	33	0.0	1338	225260	8517	Crown land
Myriophyllum elatinoides	495	20.1	-			
M. propinquum	257	0.6	722	603607	8214	Crown land reserve
Ruppia spp.	740	0.8	35	(Derwent River Wildlife Sanctuary)		Crown land
Scirpus fluitans	90	2.2	519	800728	8416	private
Triglochin procera	911	10.2	-			
Villarsia reniformis	11	0.0	624	993573	7815	Crown land

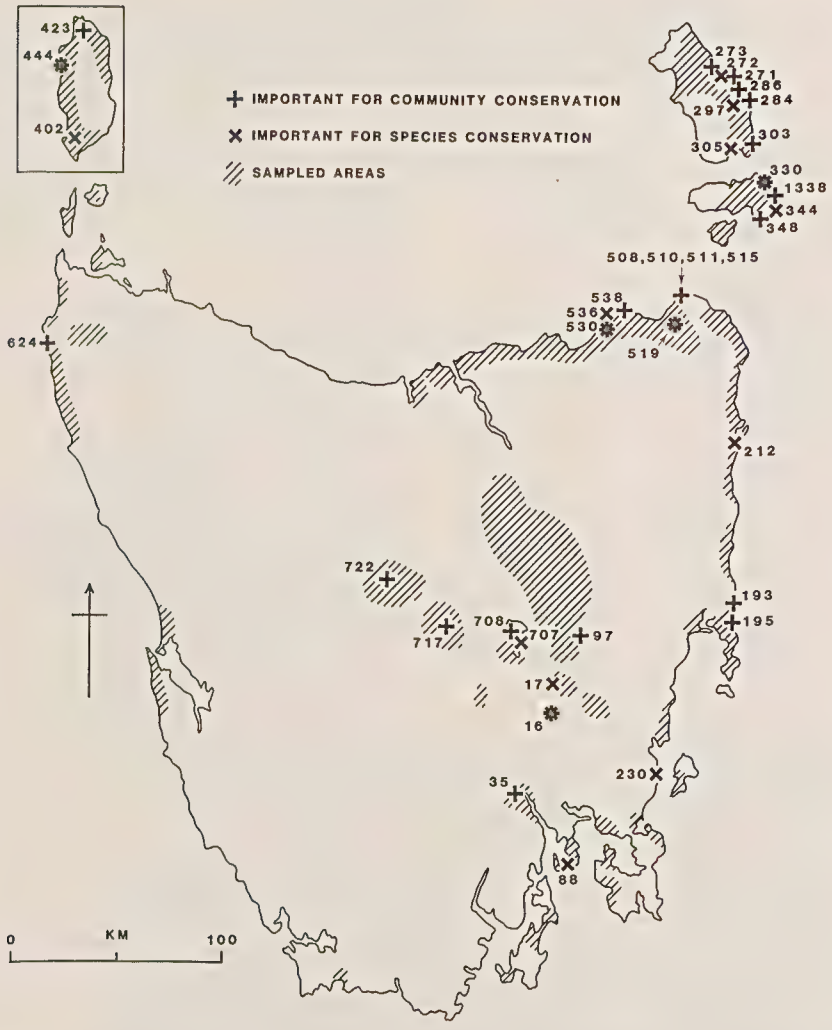

FIG. 1 - Distribution of wetlands recommended for reservation and regions in which wetlands were surveyed.

growth recur (Valk & Davis 1978). Others may depend for re-establishment on the dispersal of propagules from adjacent wetlands.

The probabilities of dispersal of species from one wetland to another are a function partly of distance and partly of the strength of the dispersal agent. Wetland species, being inhabitants of a highly disjunct environment, generally have adaptations for long distance dispersal, and thus have wide distributions. The main agents for dispersal for most species are almost certainly the wetland avifauna, and within catchments, floods (Sculthorpe 1967). Thus, the maintenance of a species complement in a particular wetland may partially depend on the maintenance of the paths of bird migration and local movement.

These paths may be disrupted by widespread drainage of surrounding wetlands, and an overall reduction in the area of wetlands may lead to a total reduction in the populations of particular bird species, and thus of the opportunities for particular wetlands to receive propagules of species eliminated through environmental fluctuations.

The Tasmanian wetland environments appear to be relatively resistant to the invasion of exotic species, which are substantially confined to the infrequently inundated zone on the margins of wetlands in agricultural country, particularly those disturbed by introduced grazing animals. Most of the native species which occupy this zone are themselves opportunistic and persist well even in the face of such invasions. Thus, wetlands appear to be suitable for small reserves in developed country, and a series of small reserves may be better for the preservation of variation in wetland communities and species than a few large reserves containing a similar number of wetlands, albeit with greater area.

A substantial reduction in area of any vegetation type is likely to lead to some extinction of localized or widespread but rare species. For example, several of the unreserved species recorded in this study might well be eliminated in Tasmania by the drainage of just one wetland.

The major conclusion of this study has to be that although the level of reservation of wetland vegetation as a whole might be construed as adequate, the reservation of species and communities, apart from those characteristic of oligotrophic environments, is markedly inadequate. This inadequacy can largely be rectified by the transfer of Crown land and some Lands Department Reserves to the status of State Reserve, but purchases of privately owned wetlands or their management as conservation areas with declared Management Plans are also necessary.

Part of the value of a study such as this one is that it focusses attention on those species and communities that are rare or endangered. It might be that intensive searches for these, now that they have been identified, will reveal other occurrences, which will enable secure reservation to be made more easily.

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APPENDIX 1

PLANT TAXA OBSERVED IN THE TASMANIAN WETLAND SURVEY.

\+ = introduced taxon m = wetland margins

DICOTYLEDONEAE

BORAGINACEAE
m *Mysotis australis* R.Br.

CALLITRICHACEAE
\+ *Callitriche stagnalis* Scop.

CARYOPHYLLACEAE
\+ *Cerastium* spp.
\+ *Sagina maritima* Don ex Sm. & Sow.
Spergularia media (L.) Presl. G,M,MW
\+ *Stellaria media* (L.) Cyrillo
S. palustris Ehrh. ex Retz. P

CHENOPODIACEAE
m *Atriplex cinerea* Poir.
\+ *A. hastata* L.
m *A. paludosa* R.Br.
\+ *A. patula* L.
Chenopodium glaucum spp. *ambiguum* (R.Br.) Murr. & Thell. ex Thell. F,LV,M,TH
Hemichroa pentandra R.Br. AR;M,MW
Pachycornia arbuscula (R.Br.) A.J.Scott AR
Suaeda australis (R.Br.) Moq. M
Sarcocornia blackiana (Ulbrich) A.J.Scott M
S. quinqueflora (Bunge ex Ung.-Sternb.) A.J. Scott AR,F,M,MW,SW

COMPOSITAE
Angianthus eriocephalus Benth. endemic GR,SW
A. preissianus (Steetz) Benth. LB
\+ *Bellis perennis* L.
m *Calocephalus lacteus* Less.
Brachycome cardiocarpa F. Muell. ex Benth. MW
B. graminea (Labill.) F. Muell. M,MCW
Centipeda minima (L.) A. Br. & Aschers.
\+ *Cirsium arvense* (L.) Scop.
\+ *C. vulgare* (Savi) Ten.
Cotula alpina Hook. f. CM,BL
C. coronopifolia L. F,G,LB,LV,M,MW,TH
C. longipes (Hook.f.) W.M. Curtis F,MW,SW,TH
C. reptans Benth. BN,CM,LB,M
m *Craspedia glauca* (Labill.) Spreng.
\+ *Gnaphalium candidissimum* Lam.
m *G. collinum* Labill. var. *monocephalum* Hook. f.

m *Gnaphalium involucratum* Forst. f.
m *G. luteo-album* L.
Helichrysum bicolor Lindl. M,MW
H. dealbatum Labill. M,MW
\+ *Hypochaeris radicata* L.
m *Lagenophora stipitata* (Labill.) Druce
\+ *Leontodon leysseri* (Wallr.) Beck
m *Leptorhynchos squamatus* (Labill.) Less.
Nablonium calyceroides Cass. endemic MCW,SW,WP
m *Senecio biserratus* Belcher
m *S. quadridentatus* Labill.
\+ *Sonchus asper* (L.) Hill
\+ *Taraxacum officinale* Weber

CONVOLVULACEAE
m *Dichondra repens* J.R. & G. Forst.
Wilsonia backhousei Hook. f. F,M
W. rotundifolia Hook.

CRASSULACEAE
Crassula helmsii (Kirk) Cockayne LV,MCW

CRUCIFERAE
\+ *Cakile edentula* (Bigelow) Hook.
Cardamine heterophylla Hook. BL,CM,M,MCW,MF,TH
\+ *Coronopus didymus* (L.) Sm.
\+ *Nasturtium officinale* R.Br.

DROSERACEAE
Drosera binata Labill. F,LV,M,MW
D. pygmaea DC. F,LB,LV,M,MW

ELATINACEAE
Elatine gratioloides A. Cunn. HG,MF

EPACRIDACEAE
m *Epacris lanuginosa* Labill.
m *E. obtusifolia* Sm.
m *E. serpyllifolia* R.Br.
m *Sprengelia incarnata* Sm.

FICOIDEAE
m *Carpobrotus rossii* Schwartes
Disphyma australe (Soland.) J.M. Black M
m *Tetragonia expansa* Murr.

GENTIANACEAE
\+ *Centaurium erythraea* Rafn.
Liparophyllum gunnii Hook. f. MF,SW
Nymphoides exigua (F. Muell) Kuntze endemic MW,P,SW
Sebaea albidiflora F. Muell. M
Villarsia exaltata (Soland. ex Sims) F. Muell.
V. reniformis R.Br. AR,BN,F,LB,LV,M,MCW,MW,TH

GERANIACEAE
\+ *Erodium cicutarium* (L.) L'Hérit. ex Ait.

GOODENIACEAE
m *Dampiera stricta* (Sm.) R.Br.
Goodenia humilis R.Br. MW
Scaevola albida (Sm.) Druce

Scaevola hookeri (de Vriese) Hook. f. BL,CM,HM,LB,MF,MW
Selliera radicans Cav. AR,BN,F,G,LB,LV,M,MCW,MW,SW,TH

HALORAGACEAE
Gonocarpus micranthus Thunb. BN,LB,MW
Haloragis brownii (Hook. f.) Schindl. LV,TH
H. heterophylla Brongn.
Myriophyllum amphibium Labill. LV,M,MCW
M. elatinoides Gaudich. AR,LB,LV,MCW,TH
M. muelleri Sond.
M. pedunculatum Hook. f. F,M,MW
M. propinquum A. Cunn. AR,L,M,MW

HYPERICACEAE
m *Hypericum gramineum* Forst. f.
H. japonicum Thunb. ex Murr. LB,MW

LABIATAE
Mentha ?diemenica Spreng. MCW,TH

LAURACEAE
m *Cassytha glabella* R.Br.

LEGUMINOSAE
m *Acacia melanoxylon* R.Br.
m *A. sophorae* R.Br.
m *A. verticillata* Willd.
m *Dillwynia glaberrima* Sm.
\+ *Lotus corniculatus* L.
\+ *Medicago* spp.
\+ *Melitotus indica* (L.) All.
m *Pultenaea dentata* Labill.
\+ *Trifolium* spp.
\+ *Ulex europaeus* L.
\+ *Vicia* spp.

LENTIBULARIACEAE
Utricularia dichotoma Labill. F,LV,M,MW,SW
U. lateriflora R.Br. F,LV,RC

LINACEAE
m *Linum marginale* A. Cunn.

LOBELIACEAE
Isotoma fluviatilis (R.Br.) F. Muell. ex Benth. MF
Lobelia alata Labill. LB,LV,M,MCW,MW,SW,TH
Pratia pedunculata R.BR. LB
P. platycalyx F. Muell. MCW,TH
P. surrepens (Hook. f.) F.E. Wimmer CM,WJ

LOGANIACEAE
Mitrasacme distylis F. Muell. MW

LYTHRACEAE
Lythrum hyssopifolia L. LV
L. salicaria L.

MALVACEAE
Lawrencia spicata (Hook.) Benth. F,LB,M,MW

MYOPORACEAE
m *Myoporum insulare* R.Br.

MYRTACEAE
m *Eucalyptus amygdalina* Labill.
m *E. ovata* Labill.
m *E. rodwayi* R.T. Baker & H.T. Smith endemic
m *E. viminalis* Labill.
m *Leptospermum laevigatum* (J. Gaertn.) F. Muell.
L. lanigerum Sm. AR,CM,F,M,MCW,MW,SW
L. scoparium J.R. & G. Forst AR,BN,F,LV,M,MCW,MW,SW
Melaleuca ericifolia Sm. AR,LV,MCW,MW,TH
M. gibbosa Labill. F,M,MW
M. squamea Labill. CM,F,FC,M,SW
M. squarrosa Donn ex Sm. BN,F,L,LV,M,MCW,MW

ONAGRACEAE
Epilobium spp. BN,LV,MCW,MW,TH

OXALIDACEAE
m *Oxalis corniculata* L.

PITTOSPORACEAE
m *Billardiera longiflora* Benth.

PLANTAGINACEAE
+ *Plantago australis*
P. bellidioides Dcne. endemic MCW,P
+ *P. coronopus* L.
+ *P. major* L.

PLUMBAGINACEAE
Limonium australe (R.Br.) Kuntze AR

POLYGONACEAE
+ *Polygonum aviculare* L.
P. plebeium R.Br.
P. strigosum R. Br.
+ *Rumex acetosella* L.
R. bidens R.Br.
R. brownii Campd. M
+ *R. conglomeratus* Murr.
+ *R. crispus* L.

PORTULACACEAE
Neopaxia australasica (Hook. f.) O. Nilss. AR,CM

PRIMULACEAE
+ *Anagallis arvensis* L.
Samolus repens (Forst. et f.) Pers. AR,F,G,M,MW,SW

PROTEACEAE
m *Banksia marginata* Cav.
m *Hakea sericea* Schrad. & J. Wendl.

RANUNCULACEAE
Ranunculus rivularis Banks & Sol. AR,LV,M.MCW,MW,TH

ROSACEAE
m *Acaena novae-zelandiae* Kirk.
\+ *Potentilla anglica* Laicharding
\+ *Rubus fruticosus* L.

RUBIACEAE
m *Galium gaudichaudii* DC.

RUTACEAE
m *Boronia parviflora* Sm.

SALICACEAE
\+ *Salix* spp.

SCROPHULARIACEAE
m *Euphrasia diemenica* Spreng.
Gratiola latifolia R.Br. MW
G. nana Benth. MW
Limosella lineata Gluck LB,LV,MCW,TH
Mazus pumilio R.Br. M
Mimulus repens R.Br. BN,F,LB,M,MW
\+ *Parentucellia* spp.
m *Veronica gracilis* R.Br.

SOLANACEAE
\+ *Solanum nigrum* L.

STYLIDIACEAE
Stylidium despectum R.Br. MW
m *S. graminifolium* Rich.

UMBELLIFERAE
Apium prostratum Vent. G,M,MCW,SW
Centella cordifolia Nannf. BN,F,LB,M,MCW,MW,TH
Eryngium vesiculosum Labill. F,LB,M,MCW,MW,TH
m *Hydrocotyle javanica* Thunb.
H. muscosa R.Br. F,LB,LV,M,MCW,MW,TH
H. pterocarpa F. Muell. LV,MCW
m *H. sibthorpioides* Lamk.
Lilaeopsis brownii A.W. Hill endemic BN,F,LB,LV,M,MCW,MW,SW,TH
m *Oreomyrrhis argentea* Hook. f.

URTICACAEA
m *Urtica incisa* Poir.

VIOLACEAE
m *Viola hederacea* Labill.

MONOCOTYLODONEAE

CENTROLEPIDACEAE
Aphelia spp.
Centrolepis aristata (R.Br.) Roem. & Schult. MW
C. fascicularis Labill. MW,LV
C. polygona (R. Br.) Hieron. MW
C. pulvinata (R.Br.) Desv. endemic MW
C. strigosa (R.Br.) Roem. & Schult. BN,LB,MW
Trithuria submersa Hook. f. MW

CYPERACEAE

Baumea acuta (Labill.) Palla F,M,MW
B. arthrophylla (Nees) Boeck. BN,F,LB,LV,M,MW,TH
B. articulata (R.Br.) S.T. Blake
B. juncea (R.Br.) Palla BN,F,LV,M,MCW,MW,TH
B. rubiginosa (Spreng.) Boeck. MCW
B. tetragona (Labill.) S.T. Blake F,M,MW
Carpha alpina R.Br. BL,CM,FC,MB,MF,SW
Carex appressa R.Br. L,LV,M,MCW,TH
C. fascicularis Soland. ex Boott in Hook. f. LV,MCW
C. gaudichaudiana Kunth. BL,CM,HM,M,MF,SW
C. tereticaulis F. Muell. M
Chorizandra cymbarica R. Br. F,M,MW
Cyperus lucidus R.Br.
C. tenellus L. f.
Eleocharis acuta R. Br. BN,F,LV,M,MCW,MW,TH
E. gracilis R.Br. SW
E. pusilla R.Br. MW,TH
E. sphacelata R.Br. BN,F,LB,M,MW
Gahnia filum (Labill.) F. Muell. AR,F,M,
m *G. grandis* S.T. Blake
m *G. sieberiana* Kunth.
G. trifida Labill. MCW,MW,TH
Gymnoschoenus sphaerocephalus (R.Br.) Hook. f. CM,F,FC,LH,MF,MW,RC,SW
m *Lepidosperma concavum* R.Br.
L. filiforme Labill. CM,F,FC,LH,M,MF,SW
L. longitudinale Labill. BN,F,LB,M,MCW,MW,TH
Schoenus apogon Poem. & Schult. F,MW
S. brevifolius R.Br. MW
S. fluitans Hook. f. M,MW
S. maschalinus Roem. & Schult. BN,LV,MCW,MW
S. nitens (R.Br.) Poir. AR,BN,F,G,LB,LV,M,MCW,MW,SW,TH
S. tesquorum J.M. Black F,MW
Scirpus caldwellii Cook
S. cernuus Vahl BN,F,LB,LV,MCW,MW,SW
S. fluitans L. AR,BN,F,M,MCW,MW
S. gunnii Boeck SW
S. inundatus (R.Br.) Poir. BN,F,L,LB,LV,MCW,MW,TH
S. montivegus S.T. Blake MF
m *S. nodosus* Rottb.
S. platycarpus S.T. Blake Z
S. productus C.B. Clarke MW
S. pungens Vahl
S. validus Vahl
Tetraria capillaris (F. Muell.) J.M. Black MW,SW

GRAMINEAE

\+ *Agropogon littoralis* (SM.) C.E. Hubbard
m *Agropyron scabrum* (Labill.) Pal. Beauv.
m *Agrostis aemula* R. Br.
m *A. avenacea* J.F. Gmel.
m *A. billardieri* R.Br.
m *A. rudis* Roem. & Schult.
\+ *A. stolonifera* L.
\+ *A. tenuis* Sibth.
\+ *Ammophila arenaria* Link.
Amphibromus archeri (Hook. f.) P.F. Morris

Amphibromus neesii Steud.
A. recurvatus J.R. Swallen F,MW
\+ *Anthoxanthum odoratum* L.
m *Danthonia caespitosa* Gaudich.
m *D. laevis* J.W. Vickery
m *D. semiannularis* (Labill.) R.Br.
m *D. setacea* R.Br.
Deyeuxia quadriseta Benth. BN,LB,M,MW
m *Dichelachne crinita* Hook.
Distichlis distichophylla (Labill.) Fassett AR,F,M,MW
m *Eragrostis ? brownii* (Kunth) Nees & Steud.
\+ *Festuca arundinacea* Schreb.
Glyceria australis C.E. Hubbard
\+ *Glyceria maxima* (Hartm.) Holmb.
Hemarthria uncinata R.Br. MW
\+ *Holcus lanatus* L.
\+ *Hordeum* spp.
\+ *Lagurus ovatus* L.
\+ *Monerma cylindrica* (Willd.) Coss. & Durieu
\+ *Parapholis incurva* (L.) C.E. Hubbard
m *Pentapogon quadrifidus* Baill.
\+ *Phalaris arundinacea* L.
\+ *P. minor* Retz.
\+ *Phleum pratense* L.
Phragmites australis (Cav.) Trin. ex Steud. F,M,MCW,MW
\+ *Poa annua* L.
m *P. labillardieri* Steud.
m *P. poiformis* Druce
\+ *Polypogon monspeliensis* (L.) Desf.
Pucinellia stricta (Hook. f.) C. Blom M
\+ *Spartina townsendii* H. & J. Groves
Sporolobus virginicus (L.) Kunth MW
\+ *Stenotaphrum secundatum* (Walt.) Kuntze
Stipa stipoides (Hook.) Veldkamp AR,G,M,SW
Tetrarrhena acuminata R.Br. F,MW
T. distichophylla (Labill.) R.Br. F,LB,M,RC
\+ *Vulpia* spp.
Zoisia matrella (L.) E.D. Merrill MW

HYDROCHARITACEAE
\+ *Elodea canadensis* Michx.
Vallisneria spiralis L. GR

HYPOXIDACEAE
m *Hypoxis hygrometrica* Labill.

IRIDACEAE
m *Diplarrena moraea* Labill.
m *Patersonia fragilis* (Labill.) Druce

JUNCACEAE
Juncus amabilis Edgar
\+ *J. articulatus* L.
J. astreptus L.A.S. Johnson
J. australis Hook. f. SW,Z
J. bufonius L. BN,LB,LV,MW
\+ *J. bulbosus* L.

Juncus caespiticius E. Mey. in Lehm. MCW,MW,TH
J. falcatus E. Mey. CM
J. holoschoenus R.Br. M
J. kraussii Hochst. AR,F,G,LB,M,MCW,SW,TH
J. pallidus R.Br. L,LV,M,MW,TH
J. pauciflorus R.Br. LV,M
J. planifolius R.Br. BN,LB,LV,M,TH
J. prismatocarpus R.Br. M
J. procerus E. Mey. AR,BN,L,LV,M,MW
J. revolutus R.Br.
J. squarrosus L.
J. subsecundus N.A. Wakefield
J. vaginatus R.Br.
J. T6 CM,FC,HM,LV

JUNCAGINACEAE
Triglochin minutissima F. Muell. L,MW
T. procera R.Br. AR,BN,F,L,LB,LV,M,MCW,MW,TH
T. striata Ruiz. & Pav. BN,F,G,LB,LV,M,MCW,MW,SW,TH

LEMNACEAE
Lemna minor L. L,LV,MCW
L. trisulca L. F
Wolffia arrhiza (L.) Hork. ex Wimm.

LILIACEAE
m *Dianella caerulea* Sims
m *D. revoluta* R.Br.

POTAMOGETONACEAE
Potamogeton australiensis A. Bennett MCW
P. pectinatus L.
P. tricarinatus F. Muell. & A. Bennett ex A. Bennett CM,MF,WR

ORCHIDACEAE
m *Cryptostylis subulata* (Labill.) Reichb. f.
m *Microtis parviflora* R.Br.
m *M. unifolia* (Forst. f.) Reichb. f.
m *Prasophyllum odoratum* R.S. Rogers
Spiranthes sinensis (Pers.) Ames ssp. *australis* (R.Br.) Kitamura F
m *Thelymitra ixioides* Swartz
m *T. retecta* H.M.R. Rupp
m *T. venosa* R.Br.

RESTIONACEAE
Empodisma minus (Hook. f.) Johnson & Cutler AR,CM,F,M,MF,MW,RC,SW
Leptocarpus brownii Hook. f. G,M,SW
L. tenax (Labill.) R.Br. BN,F,M,MW,SW
Lepyrodia muelleri Benth. F,LV,M,MW
m *L. tasmanica* Hook. f.
m *Restio complanatus* R.Br.
R. tetraphyllus Labill. FC,LV,RC,SW

RUPPIACEAE
Ruppia spp. AR,F,LB,TH

TYPHACEAE
+ *Typha latifolia* L.

XYRIDACEAE
Xyris operculata Labill. F,M,MW,SW

ZANNICHELLIACEAE
Lepilaena bilocularis T. Kirk.
L. cylindrocarpa (Kornicke) Benth. F,LB
L. preissii (Lehm.) F. Muell.

PTERIDOPHYTA

AZOLLACEAE
Azolla filiculoides Lam. LV,TH

GLEICHENIACEAE
m *Gleichenia microphylla* R.Br.

ISOETACEAE
Isoetes gunnii HM,SW

SCHIZAEACEAE
m *Schizaea bifida* Willd.

SELAGINELLACEAE
Selaginella gracillima (Kunze) Alston L,MW
S. uliginosa (Labill.) Spring F,L,LB,LV,M,MW

Also recorded were the algal genera, *Chara*, *Lamprothamnium*, *Nitella* and *Nostoc*, and the presence of mosses and/or liverworts.

AR = Asbestos Range National Park
BL = Ben Lomond National Park
BN = Bruny Neck Game Reserve
CM = Cradle Mt - Lake St Clair National Park
F = Freycinet National Park
FC = Frenchmans Cap National Park
G = Green Point Nature Reserve
GR = Gordon River State Reserve
HG = Hellyer Gorge State Reserve
HM = Hartz Mountains National Park
L = Labillardiere State Reserve
LB = Lime Bay Nature Reserve
LH = Lyell Highway State Reserve
LV = Lavinia Nature Reserve
M = Maria Island National Park
MCW = Mt Cameron West Aboriginal Site
MF = Mt Field National Park
MW = Mt William National Park
P = Pieman River State Reserve
RC = Rocky Cape National Park
SW = South West National Park
TH = Three Hummock Island Nature Reserve
WJ = Walls of Jerusalem National Park
WP = West Point Aboriginal Site
WR = Wild Rivers National Park
Z = Brown Mt - Remarkable Cave State Reserve

Reserves shown only for species not marked + or m.

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(ms. received 4.6.1982)

TWO STRIGEOID TREMATODES, *APATEMON (APATEMON) GRACILIS* (RUDOLPHI, 1819) AND *DIPLOSTOMUM (DOLICHORCHIS) GALAXIAE* n.sp., WHICH ENCYST IN THE FRESHWATER FISH *GALAXIAS AURATUS* JOHNSTON IN LAKE CRESCENT, TASMANIA.

by S.J. Smith and J.L. Hickman
The Friends' School, Hobart and Department of Zoology, University of Tasmania

(with nine tables, six text-figures and one plate)

ABSTRACT

SMITH, S.J. & HICKMAN, J.L., 1983 (31 viii): Two strigeoid trematodes, *Apatemon (Apatemon) gracilis* (Rudolphi, 1819) and *Diplostomum (Dolichorchis) galaxiae* n.sp., which encyst in the freshwater fish *Galaxias auratus* Johnston in Lake Crescent, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 117: 21-39. ISSN 0080-4703. The Friends' School, Hobart and Department of Zoology, University of Tasmania, Hobart, Tasmania.

The metacercaria and adult of *Apatemon (Apatemon) gracilis* (Rudolphi) and *Diplostomum (Dolichorchis) galaxiae* n.sp. are described and figured. Metacercarial cysts of these species occur in different parts of the endemic fish *Galaxias auratus: A. gracilis* in the body cavity, orbit and vitreous humour, and *D. galaxiae* n.sp. visible as black spots ('black-spot disease') in the musculature of the body and head. *A gracilis* which has not previously been recorded from Australia occurs in the black duck, *Anas superciliosa*, while *D. galaxiae* n.sp. infects the white-faced heron, *Ardea novaehollandiae*. The domestic duck, *Anas platyrhynchos*, is much more susceptible to experimental infection by *Apatemon gracilis* than by *D. galaxiae* n.sp. Both flukes inhabit the upper small intestine of their bird hosts. The reproductive system of *D. galaxiae* n.sp. is amphitypic. *D. galaxiae* n.sp. most closely resembles *D. heronei* Srivastava, 1954 and *D. ketupanensis* Vidyarthi, 1937; a key to species in the sub-genus *Dolichorchis* is given.

INTRODUCTION

Galaxias auratus Johnston, a small freshwater fish endemic to Lakes Sorell and Crescent in central Tasmania has been found to suffer from black-spot (or black-grub) disease (plate 1). This disease, caused by trematode cysts, has been reported from many species of freshwater fish of various taxonomic groups around the world (Singh 1956; Ganapati & Rao 1962; Hoffman 1967; and Berra & Au 1978), but has not previously been recorded in Australia. Investigation revealed that the black spots in *G. auratus* were cysts of *Diplostomum (Dolichorchis) galaxiae* n.sp., and that the fish also harboured cysts of *Apatemon (Apatemon) gracilis* (Rudolphi, 1819). *A gracilis* encysts in the body cavity, orbit and vitreous humour; and *D. galaxiae* n.sp. encysts in the musculature throughout the body and head.

In the laboratory gravid adults of both species were recovered from domestic ducklings, *Anas platyrhynchos* L., which had been fed with cysts from naturally infected *Galaxias auratus* from Lake Crescent. A black duck, *Anas superciliosa* Gmelin, killed at Calverts Lagoon southeast of Hobart, Tasmania, was found to be infected with adult flukes conforming to the description of *Apatemon gracilis*. Two white-faced herons, *Ardea novaehollandiae* Latham, killed while feeding on *Galaxias auratus* at Lake Crescent, were each found to harbour hundreds of flukes identical to adults of *Diplostomum galaxiae* n.sp. taken from experimentally infected ducklings.

Apatemon (Australapatemon) intermedius (Johnston, 1904) Dubois, 1937 is the only member of this genus previously recorded in Australia. In South Australia, it encysts in freshwater leeches, and matures in the black swan (Johnston & Angel 1951; Dubois & Pearson 1965). Six species of *Diplostomum* have previously been recorded in Australia: *D. (Adenodiplostomum) triangulare* (Johnston, 1904) Dubois & Pearson, 1967; *D. (Diplostomum) spathaceum murrayense* (Johnston & Cleland, 1938), adult described by Johnston & Angel (1941); *D. (Diplostomum) amygdalum* Dubois & Pearson, 1965; *D. (Dolichorchis) auriculosum*

PLATE 1 - Golden galaxiid, *Galaxias auratus*, from Lake Crescent. Trematode cysts *(Diplostomum galaxiae* n.sp.*)* are visible as dense black spots in musculature of the body and head. Photo: J. Lim, x 3/2.

Dubois & Pearson, 1967; *D. (Diplostomum) parvulum* Dubois & Angel, 1972; and *D. (Tylodelphys podicipinum podicipinum* Kozicka & Niewiadomska, 1960, recorded in Australia by Dubois & Angel (1972). These *Diplostomum* species infest piscivorous birds of the families Alcedinidae, Anhingidae, Ardeidae and Laridae.

MATERIALS AND METHODS

Galaxias auratus were collected at Lake Crescent on 2/4/78 and 26/6/78, and brought back to the laboratory where they were maintained in a freshwater aquarium until required for autopsy. Cysts, on removal from the host, were placed in Hank's balanced salt solution (Hank's BSS). Domestic ducklings, raised under controlled conditions, were fed metacercarial cysts in gelatin capsules (Parke Davis and Co., Empty Gelatin Capsules No.4), and dissected after intervals from 1 hour to 30 days 19 hours in the case of those fed cysts of *Diplostomum galaxiae* n.sp. and after 18 hours to 30 days 19 hours for those fed cysts of *Apatemon gracilis*. An abbreviated method of referring to time, viz. 30,19 days for 30 days 19 hours is used throughout this paper. Two black ducks were shot at Calverts Lagoon on 27/4/78 and two white-faced herons were killed at Lake Crescent on 27/6/79.. The domestic ducklings were dissected immediately they were killed. The other birds were held at 5°C pending the autopsy which was undertaken within 24 hours. For the purpose of recording the location of trematodes in the put of birds the small intestine was divided into ten equal lengths, numbered (from the pylorus) S1 to S10. Trematodes were removed, rinsed in Hank's BSS, and fixed in boiling 10% phosphate buffered formol saline.

Metacercariae were excysted *in vitro* using techniques similar to those used by Blair (1976) to excyst *Apatemon gracilis*, and by Mitchell *et al.* (1978) to excyst *Cotylurus erraticus*. Cysts were exposed to a sequence of solutions in test tubes held in an intermittently-shaking water-bath at 41 ± 1°C:

(i) 10 ml of 2% pepsin (B.D.H.) in Hank's BSS, adjusted to pH 2.0 with 0.1N HCl, for 10 minutes;
(ii) 10 ml of 0.2M sodium dithionite in Hank's BSS, for 15 minutes;
(iii) 10 ml of 0.5% pancreatin (Viokase) and 0.2% sodium taurocholate (B.D.H.) in Hank's BSS gassed to pH 7.4 with 5% CO_2 in air, for 60 minutes, or until excystment.

Between successive treatments cysts were transferred to crystal dishes under a dissecting microscope and quickly washed twice in Hank's BSS. Glassware and saline were kept at about 41°C.

In the following descriptions, unless otherwise stated, all measurements are given in microns (mean first, followed by size range in parenthesis). Drawings were made with the aid of a camera lucida.

Superfamily STRIGEOIDAE Railliet
Family STRIGEIDAE Railliet

Apatemon (Apatemon) gracilis (Rudolphi, 1819) Szidat, 1928

1. ADULT (fig. 1)

The dimensions of ovigerous adults from a naturally infected black duck and experimentally infected laboratory dukclings, are presented in table 1.

Description

Body strongly flexed dorsally at junction of fore and hindbody. Cup-shaped forebody separated by deep constriction from larger, arcuate hindbody. Oral sucker round, mouth subterminal, pre-pharynx absent; oesophagus short, bifurcating immediately posterior to small round pharynx; caeca narrows (orange-brown contents conspicuous in live worms from black duck), extending to posterior of hindbody. Ventral sucker more or less round. Discrete ovoid gland at base of foliaceous holdfast organ. Paranephridial canals large, conspicuous throughout body; excretory pore terminal. Reproductive organs confined to hindbody. Testes lobed, contiguous, tandem, posterior to ovary. Seminal vesicle coils between posterior testis and genital cone, narrowing distally, joining terminal part of uterus to form hermaphrodite duct. Ovary oval, contiguous to anterior testis. Oviduct passes dorsally, from posterodorsal border of ovary, giving rise to Laurer's canal, which opens dorsal to anterior testis. Ciliated ootype overlies dorsal lobe of anterior testis. Vitellaria confined to hindbody, ventral and overlapping gonads. Vitelline reservoir dorsal, inter-testicular. Uterus loops anteroventrally from ootype, extending along ventral border of testes, joining seminal vesicle posterior to posterior testis. Hermaphrodite duct opens through protrusible genital cone, within subterminal-dorsal copulatory bursa. Uterus contains up to 14 eggs.

Hosts

Anas platyrhynchos L. (experimental), *A. superciliosa* Gmelin.

Geographical location

Lake Crescent (fish intermediate host); Calverts Lagoon (black duck).

Date of collection

Fish 2/4/78, 26/6/78 (coll. R. White, R.B. Mawbey); black duck 27/4/78 (coll. R.B. Mawbey, S.J. Smith).

Habitat

Upper small intestine.

Material

Tasmanian Museum and Art Gallery: adults from black duck, Calverts Lagoon, K887; adults from laboratory duckling K888; excysted metacercariae K889.

Relationships

Adults recovered from a naturally infected black duck and experimentally infected laboratory ducklings fell within the range of previous descriptions of *Apatemon (Apatemon) gracilis* (Dubois 1951, Beverley-Burton 1961, Ricci & Carrescia 1961, and Vojtek 1964). This species is noted for its morphological variability and Dubois (1953) suggested that it be divided into ten sub-species. Beverley-Burton (1961), however, observed that specimens taken from the same host can be assigned to several of these sub-species, and hence considered it preferable to regard this cosmopolitan species with a wide host range, as polytypic, rather than as a collection of sub-species.

A. (Apatemon) gracilis and *A. (Australapatemon) minor* Yamaguti, 1933, have frequently been considered conspecific (Dubois 1968), and it is often impossible to determine which species is referred to when *A. gracilis* is reported, unless life-history studies have been

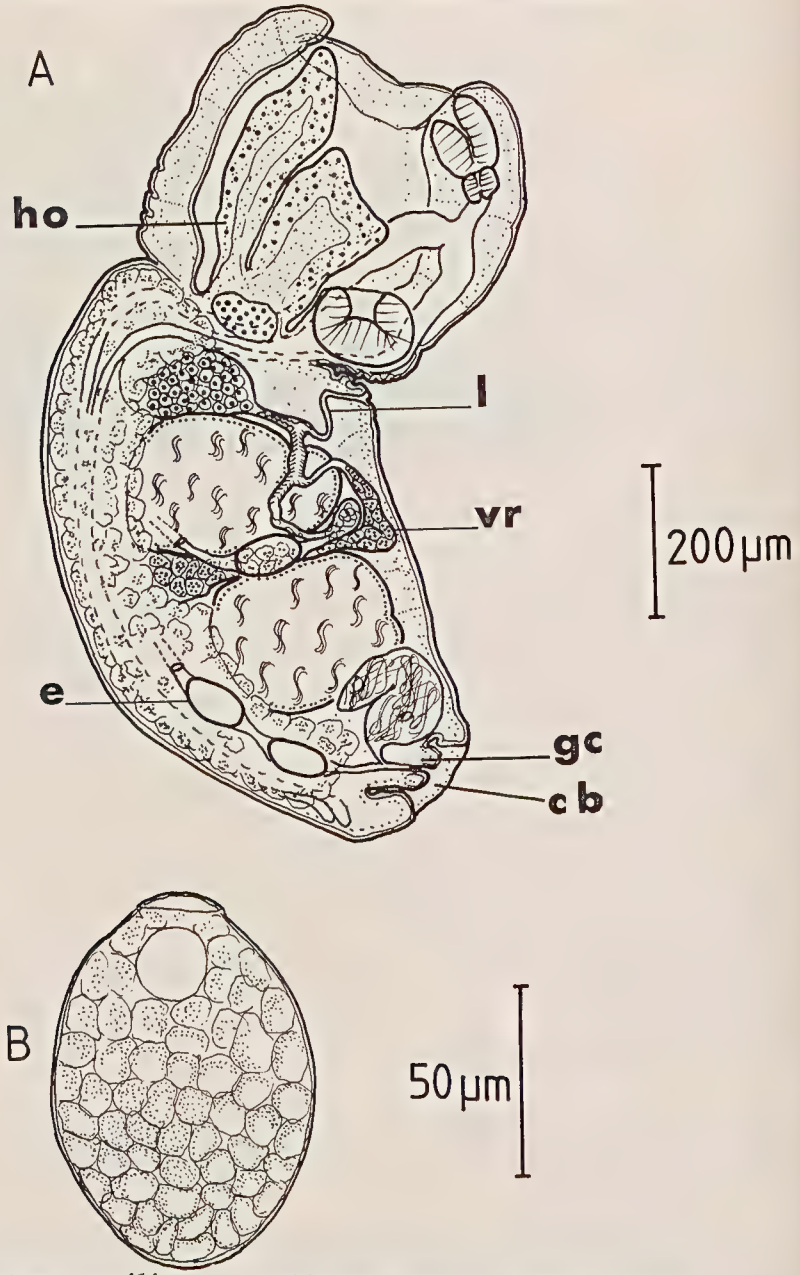

FIG. 1 - *Apatemon gracilis*. A: gravid adult after 4,21 days in experimentally infected duckling; B: egg deposited in duckling's intestine. (cb: copulatory bursa, e: egg, gc: genital cone, ho: holdfast organ, l: Laurer's canal, vr: vitelline reservoir).

made. The former species utilizes fish as intermediate hosts and the latter, leeches (Blair 1976). The present material evidently belongs to the former species.

TABLE 1

DIMENSIONS OF *APATEMON GRACILIS*.

(a) metacercariae, excysted *in vitro* after 2 hours at 41°C; (b), (c) and (d) adults recovered from experimentally infected ducklings after different periods of infection; and (e) adults from a naturally infected black duck.

	(a)	(b)	(c)	(d)	(e)
Infection period (days)	-	3,19	4,21	8,1	-
	n=4	n=5	n=6	n=5	n=3
Body length	590 (550-665)	957 (847-1028)	1335 (1225-1452)	1182 (1074-1300)	1542 (1315-1845)
Forebody:depth	264 (255-274)	355 (331-391)	397 (369-437)	360 (350-380)	510 (469-529)
length (FBL)	416 (393-469)	429 (348-499)	544 (499-590)	423 (393-469)	579 (469-741)
width	314 (300-327)	467 (433-502)	-	-	-
Hindbody:depth	144 (-)	312 (304-319)	402 (369-452)	354 (296-380)	479 (423-514)
length (HBL)	174 (166-197)	514 (454-559)	791 (650-907)	759 (680-832)	912 (786-1104)
width	129 (125-133)	346 (342-350)	-	-	-
Oral sucker:depth	72 (68-76)	87 (84-91)	103 (95-110)	85 (76-91)	86 (76-95)
length	78 (76-80)	94 (87-99)	103 (95-114)	95 (84-114)	108 (99-118)
width	80 (76-84)	93 (91-95)	-	-	-
Ventral sucker:depth	91 (87-95)	129 (114-141)	146 (122-167)	144 (129-156)	139 (114-156)
length	90 (84-99)	120 (106-133)	127 (122-137)	129 (122-133)	155 (137-167)
width	95 -	108 (99-118)	-	-	-
Pharynx:depth	34 -	52 -	64 (61-72)	64 (53-68)	34 -
length	34 -	60 (53-65)	57 (49-61)	62 (57-65)	46 -
width	32 (30-34)	44 (42-46)	-	-	-
Holdfast organ:depth	55 (49-61)	76 (53-99)	81 (61-95)	84 (76-95)	92 (84-106)
length	43 (34-46)	68 (65-72)	63 (46-76)	43 (34-53)	65 (53-72)
width	46 -	-	-	-	-
Ovary:depth	-	-	123 (103-144)	-	143 (122-175)
length			89 (84-95)	-	81 (72-125)
Anterior testis:depth	-	-	208 (175-266)	-	274 (217-346)
length	-	-	158 (114-220)	-	252 (213-304)
Posterior testis:depth	-	-	244 (213-281)	-	275 (171-388)
length	-	-	234 (220-255)	-	282 (163-418)
O.S. (1+w)/V.S. (1+w)	0.85	0.82	0.75	0.66	0.66
FBL/HBL	2.39	0.83	0.69	0.56	0.63
Eggs in uterus	-	+	+	+	+

Biology

Five out of seven ducklings fed cysts of *A. gracilis* from *Galaxias auratus* were infected, with from 2 to 37 flukes. The percentage of metacercariae recovered as adults varied from 8 to 93, and the maximum longevity recorded was 8,1 days. Adults were concentrated in S4 after 0.18 days, S2 after 3,19 days, S3 after 4,21 days, and S2 after 8,1 days. A black duck killed at Calverts Lagoon contained 27 adult *A. gracilis*, concentrated in S2. The distribution of adults in naturally and experimentally infected hosts is shown in figure 2.

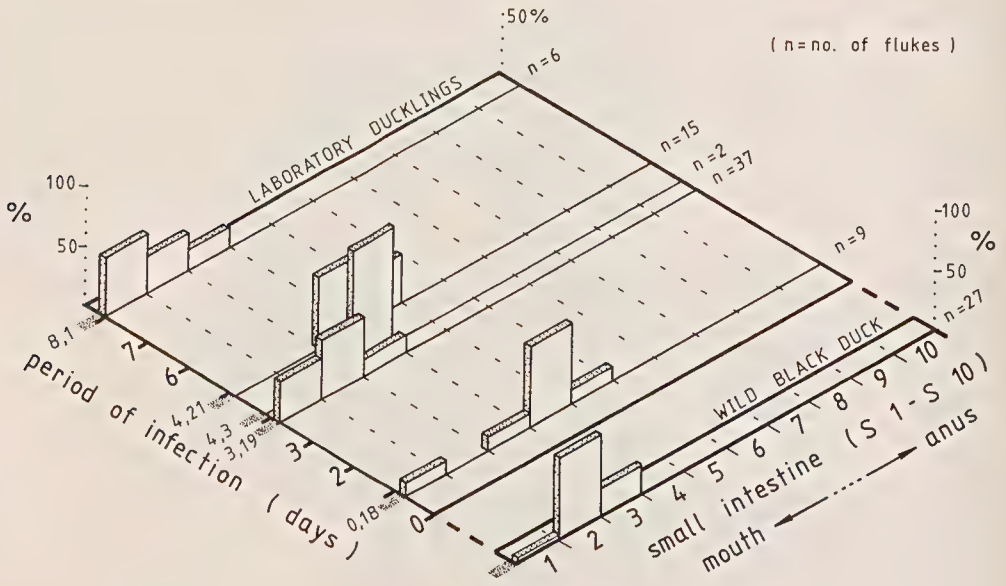

FIG. 2 - *Apatemon gracilis*. Distribution in the digestive tracts of a wild black duck, and laboratory ducklings. (n = number of flukes)

Excysted metacercariae are very immature and genital primordia barely discernible. After 0,18 days in a laboratory duckling little growth or development had occurred; however, growth proceeded rapidly over the next few days. As the reproductive organs developed, the hindbody grew from being a stumpy appendage to being larger than the forebody (fig. 3). After 3,19 days the FBL/HBL ratio had decreased from 2.39 for excysted metacercariae, to 0.83. At this stage the adults were mature and producing eggs. The hindbody continued to grow after egg production had commenced and after 8,1 days the FBL/HBL ratio was 0.66. The number of uterine eggs was not directly related to the age of ovigerous adults (table 2). A maximum of 14 eggs was found in flukes after 4,3 and 4,21 days; however, after 8,1 days the maximum number of eggs in any fluke was only five. The maximum number of eggs found in flukes infecting the black duck was seven.

2. EGG (fig. 1)

The broadly oval egg is operculate and densely packed with granular vitelline cells. Colourless when formed, the egg-shell is tanned golden as it passes through the uterus. A clear spherical body, about 19 µm diameter, underlies the operculum. The dimensions of live and fixed eggs in flukes from laboratory ducklings and fixed eggs in flukes from a wild black duck, are shown in table 3. There was little difference in the size of fixed eggs from different hosts, however, fixed eggs were smaller than live eggs.

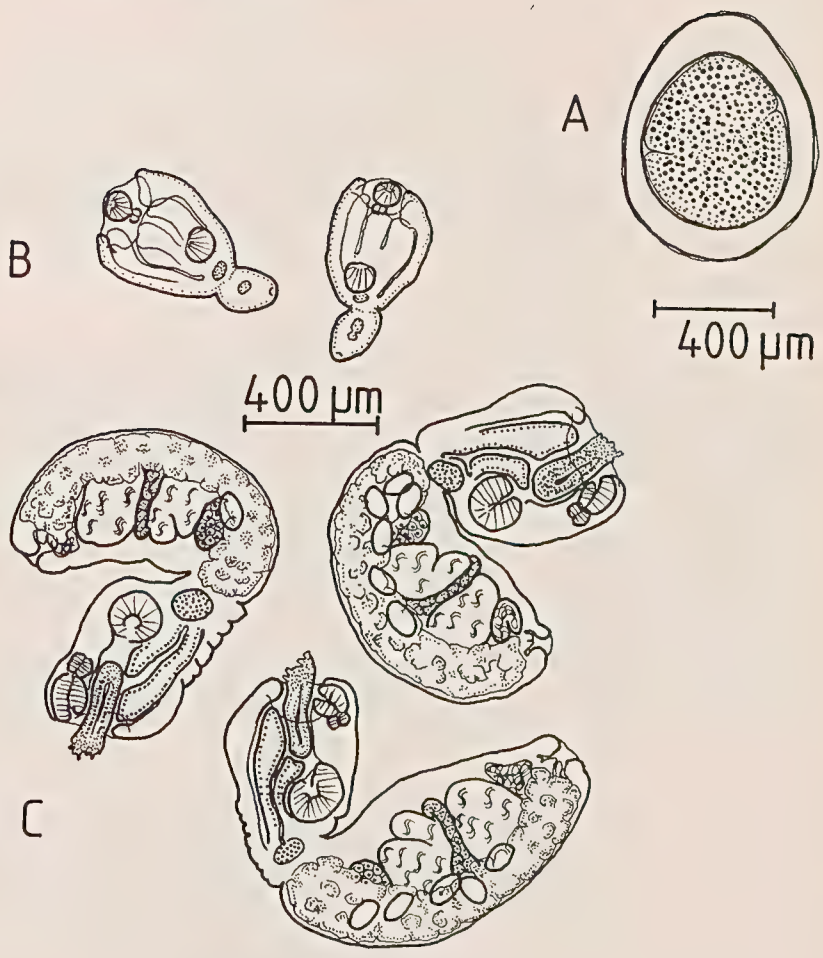

FIG. 3 - *Apatemon gracilis*. A: metacercarial cyst from *Galaxias auratus*; B: excysted metacercariae after 2 hours at 41°C; C: gravid adults after 8,1 days in laboratory duckling - forebody of each adult adhering to an intestinal villus from host (B and C drawn to same scale).

TABLE 2

THE NUMBER OF UTERINE EGGS IN ADULT *APATEMON GRACILIS*. (a) from experimentally infected ducklings, and (b) from wild black duck.

	Infection period (days)	Number of flukes	Number of uterine eggs	
			Mean	Range
(a)	3,19	30	0.5	(0-1)
	4,3	2	11.0	(8-14)
	4,21	11	3.5	(0-14)
	8,1	5	2.8	(1-5)
(b)	-	11	2.0	(0-7)

TABLE 3

DIMENSIONS OF EGGS OF *APATEMON GRACILIS*.

Host	Live/ fixed	Number of eggs	Length	Width
Duckling 1	live	6	103 (95-106)	71 (68-72)
Duckling 1	fixed	6	99 (95-103)	63 (61-68)
Duckling 2	fixed	9	99 (95-106)	61 (57-67)
Black duck	fixed	6	97 (87-103)	59 (53-68)

3. METACERCARIA

Metacercarial cyst (fig. 3)

The thick-walled, white, oval to pyriform cyst, most frequently occurs in the body cavity of *Galaxias auratus*, particularly in connective tissue adjacent to the intestine. It is also frequently associated with the eye, either in the vitreous humour, or just outside the eyeball, near the optic nerve. The cyst sometimes occurs between the peritoneum and muscle. Ten out of fourteen fish collected in June 1978 and June 1979, from the Clyde River where it enters Lake Crescent, were infected with *Apatemon gracilis*. The average number of cysts per infected fish was 5.5 (1-17) and the average size of the fish was 6.4 (4.8-9.9) cm. Eighty percent of these cysts were in or next to the body cavity, 18% were behind the eyeball next to the optic nerve and 2% were in the vitreous humour. The resilient cyst wall is translucent and homogenous, varying in thickness up to about 220 µm. A thin outer membrane, presumably of host origin, sometimes connects adjacent cysts. The densely packed contents of the cyst are opaque. Dimensions of ten cysts from the body cavity and two cysts from the vitreous humour of the eye, are shown in table 4. There is no marked difference in size or morphology of the cysts from different locations in the fish host.

TABLE 4

CYSTS OF *APATEMON GRACILIS* FROM DIFFERENT FISH HOSTS.
Dimensions of live metacercarial cysts, dissected from naturally infected *Galaxias auratus*; from the brook stickleback, *Eucalia inconstans*, in North Dakota, U.S.A. (Hoffman 1959); and from the rainbow trout *Salmo gairdneri*, in Scotland (Blair 1976).

Host fish	Number of cysts	External dimensions		Internal dimensions	
		Length	Width	Length	Width
G. auratus (body)	10	886(816-968)	718(650-756)	587(423-650)	493(348-552)
G. auratus (eye)	2	877(847-907)	665(650-680)	544(529-559)	529(484-575)
E. inconstans	-	1000	600	507	444
S. gairdneri	10	605(542-660)	396(356-426)	503(465-542)	293(279-310)

Excysted metacercaria (fig. 3)

The dimensions of some excysted metacercariae are presented in table 1. The forebody is cup-shaped and relatively larger than in the adult worm. The oral and ventral suckers, pharynx and holdfast organ are well-developed in the forebody, but genital primordia are barely discernible in the rudimentary hindbody. Body fluids and lipid droplets move through large paranephridial canals, throughout the body of live worms.

S.J. Smith and J.L. Hickman

Family DIPLOSTOMIDAE Poirier

DIPLOSTOMUM (DOLICHORCHIS) GALAXIAE n.sp.

1. ADULT (fig. 4)

The description of the adult of this new *Diplostomum* species is based on gravid flukes recovered from experimentally infected laboratory ducklings and naturally infected white-faced herons. The species is named after the endemic Tasmanian fish, *Galaxias auratus*, which serves as its second intermediate host. Dimensions of the holotype and other ovigerous and non-ovigerous adults, from naturally infected white-faced herons, are shown in tables 5 and 6.

TABLE 5

OVIGEROUS ADULTS OF *DIPLOSTOMUM GALAXIAE* n.sp.
Dimensions of the holotype and other ovigerous adults,
of 'sinistral' and 'dextral' types, from the white-faced heron.

Sample size	'Sinistral' n = 11	'Dextral' n = 14	Holotype n = 1 ('sinistral')
Body length	957 (892-1058)	1002 (832-1074)	937
Forebody:depth	133 (121-166)	141 (106-±97)	-
length (FBL)	549 (484-665)	517 (393-635)	575
width	342 (302-401)	369 (287-438)	318
Hindbody:depth	269 (242-302)	266 (227-287)	-
length (HBL)	437 (348-499)	467 (378-499)	378
width	289 (272-302)	296 (204-333)	280
Oral sucker:depth	49 (46-43)	64 (53-76)	-
length	65 (57-76)	64 (57-68)	65
width	63 (61-67)	71 (59-84)	65
Ventral sucker:depth	-	53 -	-
length	63 (59-68)	62 (57-65)	53
width	73 (67-80)	70 (61-80)	70
Pharynx:length	49 (46-57)	48 (46-49)	46
width	36 (34-38)	34 -	38
Left lappet:length	87 (76-91)	81 (76-84)	91
width	46 (42-53)	36 (27-49)	53
Right lappet:length	87 (76-95)	81 (68-99)	76
width	49 (46-53)	40 (34-49)	53
Holdfast organ:depth	70 (68-72)	72 (68-76)	-
length	136 (110-160)	154 (133-179)	141
width	136 (114-148)	-	141
Ovary:depth	-	95 -	-
length	68 (61-76)	65 (42-84)	61
width	90 (80-95)	85 (65-106)	91
Anterior testis:depth	163 -	176 (141-194)	-
length	91 (80-114)	102 (78-144)	84
width	121 (87-141)	130 (84-198)	125
Posterior testis:			
left lobe depth	137 -	144 (122-167)	-
length	141 (114-198)	156 (110-213)	118
width	98 (76-114)	78 (61-95)	103
right lobe depth	123 (110-133)	143 (125-167)	-
length	158 (114-205)	164 (110-213)	133
width	96 (80-110)	97 (68-125)	87
O.S.(1+w)/V.S.(1+w)	0.94	1.02	1.06
FBL/HBL	1.26	1.11	1.52
Number of uterine eggs	1.90 (1-6)	3.14 (1-11)	2

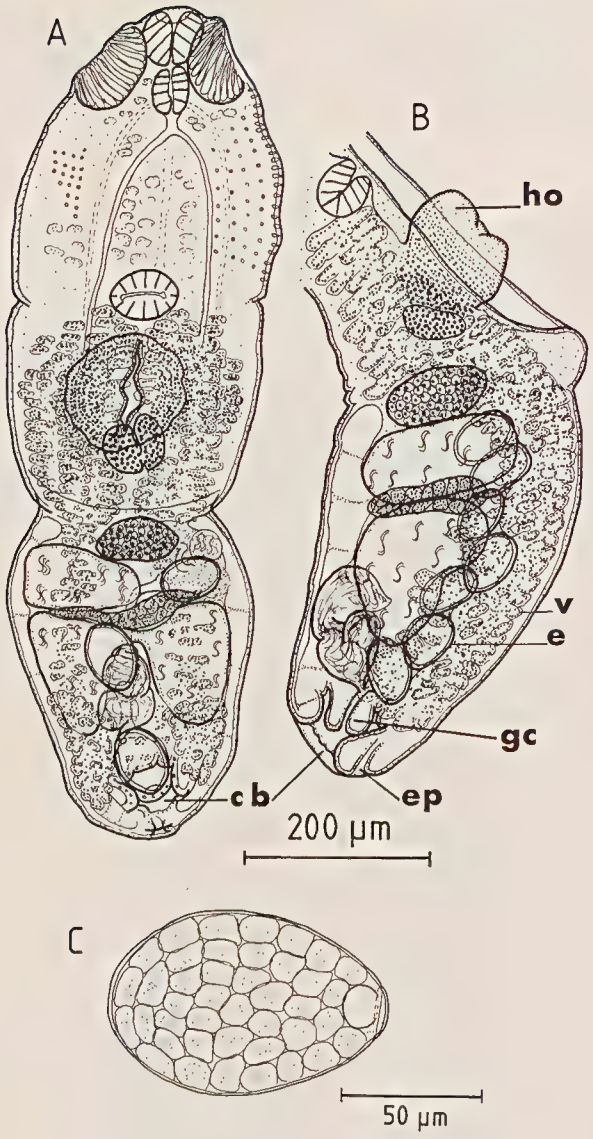

FIG. 4 - *Diplostomum galaxiae* n.sp.
A: gravid adult, sinistral anterior testis, from white-faced heron, dorsal view.
B: gravid adult, dextral anterior testis, from white-faced heron, lateral view of hindbody.
C: egg (cb: copulatory bursa, e: egg, ep: excretory pore, gc: genital cone, ho: holdfast organ, v: vitellaria).

Description

Forebody elongate, more or less rectangular, anterior body trilobate, posterior and posterolateral borders recurved ventrally. Hindbody conical, dorsally flexed, distinct from forebody. Tegumental spines on forebody diminishing in size posteriorly; hindbody aspinous. Tegumental gland cells distributed over anterior half of forebody. Oral sucker round, situated on prominent anterior protuberance bordered by well-developed crescentic lappets. Ventral sucker transversely oval; holdfast organ mobile, mushroom-shaped; both protrude into concavity of forebody. Paranephridial canals anastomose throughout body. Excretory pore terminal. Mouth subterminal ventral; prepharynx absent; caeca narrow inconspicuous, diverging immediately posterior to small oval pharynx, then extending into hindbody. Bipartite gland at base of large, holdfast organ. Anterior testis dextral or sinistral, round to wedge-shaped. Posterior testis bilobed, elongate lobes joined by narrow anterodorsal commissure. Seminal vesicle voluminous coiled, lying between lobes of posterior testis, narrowing posteriorly to form ejaculatory duct, which joins uterus. Ovary oval sub-median, situated anteriorly in hindbody. Oviduct extends posterolaterally to ootype. Ootype surrounded by Mehlis' gland, opposite posterior half of anterior testis. Laurer's canal opens dorsally, at level of anterior testis. Seminal receptacle lateral to ovary. Vitellaria occupy posterior half of forebody, extending anteriorly to posterior border of ventral sucker; distribution in hindbody mainly ventral, lateral. Vitelline reservoir intertesticular. Uterus loops antero-ventrally, then extends posteriorly, ventral to seminal vesicle, uniting with ejaculatory duct. Short hermaphordite duct traverses small protrusible genital cone, within subterminal dorsal copulatory bursa. Up to 11 eggs in uterus.

The reproductive system of this species is amphitypic. In one wild host, a white-faced heron, 58% of 92 mature adults (i.e. with vitellaria producing phenolic egg-shell precursors), had a sinistral anterior testis and the remaining 42% had a dextral anterior testis. The position of the testis is always clearly sinistral or dextral - there are no intermediates. No other distinct morphological differences could be found between the 'sinistral' and 'dextral' types (tables 5 and 6). However, only 30% of the 'sinistral' adults were ovigerous, compared with 54% of the 'dextral' adults; and there was a slight difference in the number of uterine eggs in each type: 1.9 (1-6) in 'sinistral' adults, and 3.1 (1-11) in 'dextral' adults. Fecundity of *D. galaxiae* n.sp. may be related to the position of the anterior testis.

Hosts

Anas platyrhynchos L. (experimental); *Ardea novaehollandiae* Latham.

Geographical location

Lake Crescent.

Date of collection

Fish intermediate host 2/4/78, 26/6/78 (coll. R. White, R.B. Mawbey); white-faced herons 27/6/79 (coll. R.B. Mawbey, S.J. Smith).

Habitat

Upper small intestine.

Type material

Tasmanian Museum and Art Gallery: holotype K884, ringed (gravid adult); paratypes K885 (adults) and K886 (excysted metacercariae).

Relationships

This species has the characteristics of the subgenus *Dolichorchis* Dubois, 1961, i.e. asymmetrical anterior testis, elongated lobes of the posterior testis joined by a narrow dorsal commissure and the presence of a genital cone. Seven species of *Diplostomum* have previously been assigned to the subgenus *Dolichorchis*, however only one of these, *Diplostomum auriculosum*, has been recorded in Australia. All seven species reach maturity in piscivorous birds. No intramolluscan developmental stages have yet been recorded. The metacercarial stage has only been described for two of the species: *Diplostomum heronei* Srivastava, 1954 (syn. *D. ketupanensis* sensu Ganapati and Rao, 1962 nec Vidyarthi, 1937, according to Williams, 1967), and *D. tregenna* Nazmi, 1932. The metacercaria of *D. heronei* encysts in the musculature of freshwater fish in India; however, according to Khalil (1963),

the metacercaria of *D. tregenna* remains unencysted in the brain of *Clarias*, a fish of the River Nile. The only other previous record of the metacercaria of a *Diplostomum* species encysting in fish is the metacercaria, *Diplostomulum pigmentata* Singh, 1956, which encysts in the muscles of freshwater cyprinoid fish in the Allahabad region of India, where *D. heronei* and *D. ketupanensis* Vidyarthi, 1937, have been recorded.

Of the seven species previously assigned to the subgenus *Dolichorchis*, *Diplostomum galaxiae* n.sp. most closely resembles *D. heronei* and *D. ketupanensis* in general morphology, distribution of vitellaria, shape and size of anterior testis and relative size of lappets. In all three species, vitellaria are extensively distributed in the posterior part of the forebody, extending anteriorly as far as the ventral sucker, whereas in *D. marahoueense* Baer, 1957, and *D. auriculosum* Dubois and Pearson, 1967, vitellaria are restricted in the forebody, to a narrow zone around the holdfast organ, and do not extend anteriorly as far as the ventral sucker. In *D. buteii* Vidyarthi, 1937, and *D. tregenna*, vitellaria are distributed anteriorly well beyond the ventral sucker nearly to the pharynx. Dubois (1968), considers that *D. duboisi* Anantaraman and Balasubramaniam, 1953, is a synonym of *D. buteii* and the present authors agree.

Diplostomum ketupanensis Vidyarthi, 1937 is very similar in morphology to *D. heronei*, however, the body and organs of the former are about two to three times larger than those of the latter, and whereas uterine eggs are absent in the former, four or more eggs may occur in the uterus of the latter. Williams (1967), considered that *D. ketupanensis* sensu Ganapati and Rao, 1962, but not *D. ketupanensis* Vidyarthi, 1937, is a synonym of *D. heronei*, and the present authors concur. *D. galaxiae* n.sp. is significantly smaller than *D. ketupanensis* Vidyarthi, 1937, has a more elongate forebody, and contains up to 11 uterine eggs. The position of the anterior testis is variable in the former and sinistral in the latter.

D. heronei and *D. galaxiae* n.sp. are similar in size, however the former has a flat, round forebody, whereas that of *D. galaxiae* n.sp. is elongate and very concave. The anterior testis of *D. heronei* is dextral and the posterior testis is relatively longer than that of *D. galaxiae* n.sp. The excysted metacercariae of *D. heronei* is markedly smaller and has a relatively rounder forebody and larger hindbody than that of *D. galaxiae* n.sp. The discovery of the intramolluscan developmental stages of these species would elucidate their relationship, however it is presently considered that differences in morphology of adults and metacercariae and the different intermediate and definitive hosts, warrant their specific separation.

A key to the species of the subgenus *Dolichorchis* is given below.

1a. Anterior testis L-shaped; extends width of hindbody.
Intestinal parasite of the Indian pariah kite, in S.E. India; and *Buteo rufinus rufinus*, in N. India. ... *D. buteii* Vidyarthi, 1937
Syn.: *Bolbophorus orientalis* Vidyarthi, 1938
D. duboisi Anantaraman and Balasubramaniam, 1953

1b. Anterior testis not L-shaped; lateral in anterior hindbody ... 2

2a. Vitellaria not distributed anteriorly beyond ventral sucker ... 3

2b. Vitellaria distributed anteriorly beyond ventral sucker.
Diplostomulum encysted in brain of freshwater fish in River Nile.
Adult intestinal parasite of Egyptian kite, Cairo, Egypt
..... *D. tregenna* Nazmi, 1932

3a. Vitellaria restricted to region of holdfast organ; anterior distribution distribution not reaching ventral sucker ... 4

3b. Vitellaria distributed widely in posterior forebody; anterior distribution reaching ventral sucker ... 5

4a. Ventral sucker larger than oral sucker. Lappets projecting anterior to oral sucker.
Intestinal parasite of darter, in Queensland, Australia
..... *D. auriculosum* Dubois and Pearson, 1967

4b. Oral sucker larger than ventral sucker. Lappets not projecting anterior to oral sucker.

Parasite of upper small intestine of fishing owl, Ivory Coast
..... *D. marahoueense* Baer, 1957

5a. Small flukes, body length less than 1.5 mm ... 6

5b. Large flukes, body length more than 1.5 mm.
Intestinal parasite of northern brown fishing owl, in N India
..... *D. ketupanensis* Vidyarthi, 1937

6a. Forebody flat, round; anterior testis dextral.
Metacercaria encysts in muscles of freshwater fish, Andhra Pradesh.
Adult intestinal parasite of grey pond heron in N. and E. India
..... *D. heronei* Srivastava, 1954
Syn.: *D. ketupanensis* sensu Ganapati and Rao, 1962

6b. Forebody elongate, ± rectangular, concave; anterior testis variable (reproductive system amphitypic).
Metacercaria encysts in muscles of freshwater fish, Lake Crescent.
Adult parasite in upper small intestine of white-faced heron, Tasmania, Australia ..... *D. galaxiae* n.sp.

TABLE 6

NON-OVIGEROUS ADULTS OF *DIPLOSTOMUM GALAXIAE* n.sp.

Dimensions of mature (i.e. vitellaria producing phenolic egg-shell precursors), non-ovigerous adults of 'sinistral' and 'dextral' types, from the white-faced heron.

Sample size	'Sinistral' n=17	'Dextral' n=14
Body length	889 (771-1058)	983 (847-1210)
Forebody:depth	106 (91-121)	132 (121-151)
length (FBL)	496 (423-635)	581 (469-711)
width	351 (318-408)	363 (302-408)
Hindbody:depth	234 (227-257)	259 (242-272)
length (HBL)	396 (333-484)	429 (348-544)
width	292 (272-333)	292 (272-318)
Oral sucker:depth	60 (49-76)	66 (57-70)
length	63 (49-68)	65 (49-72)
width	70 (61-76)	67 (61-70)
Ventral sucker:depth	61 -	70 (65-76)
length	62 (53-68)	63 (57-72)
width	76 (68-84)	72 (61-84)
Pharynx:length	51 (42-57)	53 -
width	38 (30-46)	35 (32-38)
Left lappet:length	81 (72-99)	84 (72-91)
width	40 (30-53)	39 (34-46)
Right lappet:length	80 (68-95)	81 (76-87)
width	41 (30-57)	39 (30-46)
Holdfast organ:depth	75 (68-84)	81 (68-91)
length	125 (114-133)	138 (114-167)
width	137 (129-148)	130 (114-156)
Ovary:depth	76 -	-
length	76 (68-91)	66 (65-68)
width	89 (76-106)	82 (80-84)
Anterior testis:depth	148 -	103 (91-114)
length	100 (80-114)	109 (95-118)
width	117 (95-171)	108 (103-114)
Posterior testis:		
left lobe depth	122 -	115 (95-137)
length	162 (148-190)	163 (137-190)
width	106 (95-118)	103 -
right lobe depth	109 (95-114)	108 (99-114)
length	164 (129-190)	126 (103-152)
width	101 (87-118)	99 -
O.S.(l+w)/V.S.(l+w)	0.96	0.98
FBL/HBL	1.25	1.35

Biology

Three out of six ducklings fed cysts of *D. galaxiae* n.sp. from *Galaxias auratus* became infected. Each infected bird, however, harboured only one fluke. The average infectivity rate of metacercariae in these ducklings was about 1 in 100. Although ducklings are not very susceptible hosts for *D. galaxiae* n.sp., two flukes did grow to maturity. Excysted metacercariae are about half adult size, and genital primordia are discernible in the relatively short, stumpy hindbody. As growth occurs, the reproductive system develops and the hindbody increases in size relative to the forebody. One small, immature fluke was found in S7, 10 hours after infection of a duckling (fig. 5). After 4,3 days, one specimen was living in S1, and had grown to adult size and form. It was sexually mature, with vitellaria producing phenolic egg-shell precursors. Sperm filled the seminal vesicle, but no uterine eggs were present. After 12,4 days, one specimen was living in S1, and contained one uterine egg.

The distribution of adults in two white-faced herons killed while feeding on galaxiids at Lake Crescent, is shown in figure 5. They occurred from S1 to S6, but were concentrated in S2 and S3.

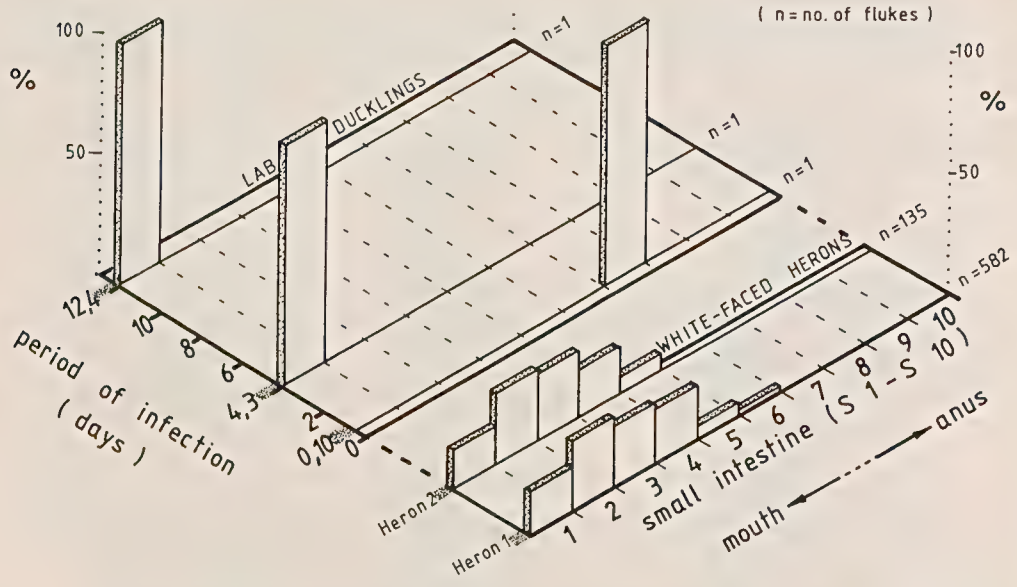

FIG. 5 - *Diplostomum galaxiae* n.sp. Distribution in digestive tracts of laboratory ducklings, and wild, white-faced herons.

2. EGG (fig. 4)

The broadly oval egg has a small round operculum and is densely packed with granular vitelline cells. The egg-shell is relatively thin, clear when formed, but becomes tanned yellow. A clear sphere about 24 µm diameter, underlies the operculum. The dimensions of live eggs taken from the lumen of the upper small intestine of infected herons, and dimensions of fixed uterine eggs of 'sinistral' and 'dextral' adults from the same hosts are shown in table 7.

TABLE 7

DIMENSIONS OF EGGS OF *DIPLOSTOMUM GALAXIAE* n.sp.
Dimensions of live and fixed eggs produced by adults in naturally infected white-faced herons.

Type	Live/ fixed	Number of eggs	Length	Width
Mixed	live	15	95 (89-101)	65 (63-67)
'Sinistral'	fixed	10	98 (91-103)	59 (53-65)
'Dextral'	fixed	12	97 (87-99)	60 (53-65)

3. METACERCARIA

Metacercarial cyst (fig. 6)

The entire black cyst is composed of a thin, but resilient, transparent inner layer of parasite origin, and a thick opaque cellular outer layer of host origin. The 'inner cyst', which separates readily from the 'outer cyst', is oval. It encloses a curled metacercaria, partially surrounded by densely packed coarse lipid droplets. The outermost layer of the 'outer cyst', or host reaction coat, consists of black pigmented melanocytes, which make even deep-seated cysts conspicuous in the translucent body of *Galaxias auratus*. Cysts are distributed widely in the musculature of the body and head, causing 'black spot' or 'black grub' disease. The dimensions of the cyst are shown in table 8.

TABLE 8

CYSTS OF *DIPLOSTOMUM GALAXIAE* n.sp.
Dimensions of live metacercarial cysts, dissected from naturally infected *Galaxias auratus*.

	Number	Length	Width
External dimensions 'outer cyst'	10	1125 (1043-1210)	866 (771-937)
External dimensions 'inner cyst'	10	629 (575-643)	354 (333-386)

All of fourteen fish collected in June 1978 and June 1979, from the Clyde River where it enters Lake Crescent, were infected with *Diplostomum galaxiae* n.sp. The average number of cysts per fish was 42.7 (10-104), and the average size of the fish was 6.4 (4.8-9.9) cm.

Excysted metacercaria (fig. 6)

The size and development of excysted metacercariae varies greatly (table 9). The forebody is relatively large and elongate and the hindbody, a rudimentary stump. Gonadal primordia are visible in advanced metacercariae, and 'dextral' and 'sinistral' types are often discernible. When 39 metacercariae, dissected from fish collected in June 1979, were excysted, 51% were mature enough to distinguish the position of the anterior testis; 55% of these were 'dextral' and 45% 'sinistral'. In advanced metacercariae, the oral sucker, pharynx and caeca are formed, lappets and holdfast organs are well-developed and the bilobed gland at the base of the holdfast organ is conspicuous. The forebody tegument is spinous, spines diminishing in size posteriorly, and the hindbody tegument is aspinous. Large paranephridial canals, through which body fluids and small lipid droplets move, anastomose throughout the body. The genital pore is slightly dorsal to the terminal excretory pore.

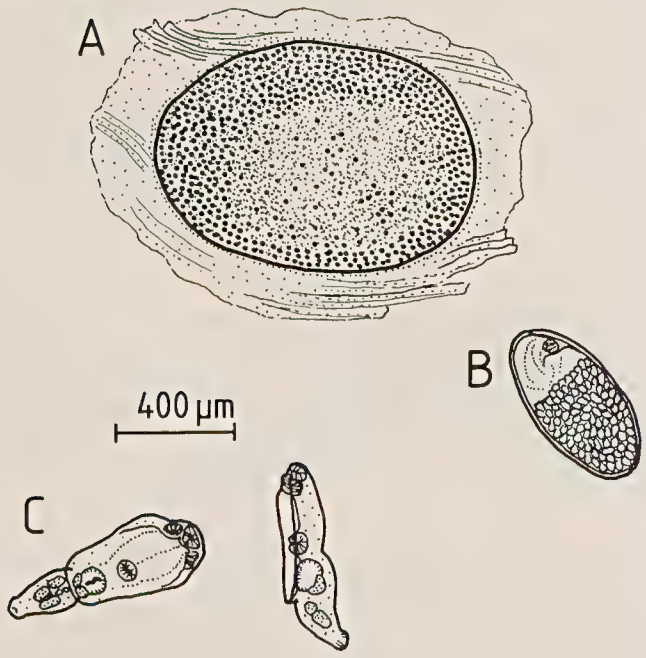

FIG. 6 - *Diplostomum galaxiae* n.sp.
A: black metacercarial cyst embedded in muscle of fish host.
B: oval 'inner cyst' removed from thick cellular 'outer cyst'.
C: excysted metacercariae after 3 hours at 41°C. (A,B and C are drawn to same scale.)

DISCUSSION

Neither of the two strigeoid species encysting in *Galaxias auratus* at Lake Crescent, has previously been recorded in Australia. *Apatemon (Apatemon) gracilis* and *Diplostomum (Dolichorchis) galaxiae* n.sp. encyst in different tissues of the fish host and infect different definitive hosts. Domestic ducklings are much more susceptible to experimental infection by *A. gracilis* than by *D. galaxiae* n.sp. - not surprisingly considering that anatids are the main definitive hosts for *A. gracilis* around the world, whereas there are no previous records of a species in the subgenus *Dolichorchis* infecting an anatid. A black duck, *Anas superciliosa*, shot at Calverts Lagoon 100 km from Lake Crescent, was found to harbour *A. gracilis*, but not *D. galaxiae* n.sp., and two white-faced herons, shot at Lake Crescent, harboured only *D. galaxiae* n.sp., despite the fact that about 70% of the fish being eaten by the herons contained cysts of *A. gracilis*.

The cercariae and metacercariae of *A. gracilis* are known to occur in Iceland and Scotland (Blair 1976), Wales (Crocombe 1959), central Europe (Vojtek 1964), Japan (Yamaguti 1933), and North America (Hoffman 1959, Lester 1974). The genera *Ancylastrum* and *Lymnaea* serve as molluscan hosts and the fish intermediate hosts include members of the families Cobitidae, Cottidae, Eleotridae, Gasterosteidae, Gobiidae and Salmonidae. Cysts from these fish intermediate hosts are very similar in morphology, but vary in size. The sizes of cysts from fish in Tasmania, the U.S.A. and Scotland, were shown in table 4. The external cyst dimensions vary much more between host species than do the internal cyst dimensions. Cyst wall thickness is apparently related to the identity of the fish host.

TABLE 9

EXCYSTED METACERCARIAE OF *DIPLOSTOMUM GALAXIAE* n.sp.
Dimensions of metacercariae excysted *in vitro* after 3 hours at 41°C: (a) too immature to distinguish anterior testis, (b) 'sinistral' type, (c) 'dextral' type.

	(a) n=11	(b) n=7	(c) n=13
Body length	401 (355-461)	691 (582-816)	665 (575-756)
Forebody:length	319 (287-363)	513 (438-605)	479 (393-559)
width	176 (156-228)	213 (194-232)	218 (194-247)
Hindbody:length	82 (68-98)	183 (144-227)	186 (151-204)
width	68 (57-72)	123 (106-137)	123 (114-148)
Oral sucker:length	46 (40-49)	54 (51-57)	55 (46-61)
width	45 (42-46)	49 (46-53)	52 (42-65)
Ventral sucker:length	40 (38-46)	42 (38-46)	45 (38-51)
width	44 (42-48)	47 (42-51)	52 (42-63)
Pharynx:length	29 (25-34)	33 (30-40)	36 (30-42)
width	21 (19-23)	25 (23-29)	25 (23-29)
Left lappet:length	49 (46-49)	70 (61-72)	70 (61-72)
width	31 (27-34)	38 (34-42)	41 (36-42)
Right lappet:length	46 (42-49)	69 (57-76)	71 (61-80)
width	30 (27-34)	38 (30-44)	43 (34-61)
Holdfast organ:length	69 (68-72)	104 (99-114)	107 (91-114)
width	74 (53-76)	81 (76-87)	81 (72-91)
Ovary:length	-	22 (19-23)	27 -
width	-	24 (23-25)	23 -
Anterior testis:length	-	38 (34-46)	39 (34-46)
width	-	30 (23-38)	34 (27-42)
Posterior testis:			
left lobe length	-	41 (34-49)	47 (38-53)
width	-	27 (23-30)	29 (23-34)
right lobe length	-	42 (34-49)	43 (34-49)
width	-	28 (27-30)	31 (27-38)
O.S.(l+w)/V.S.(l+w)	1.08	1.16	1.10
FBL/HBL	3.89	2.80	2.58

The molluscan hosts of the strigeoid species at Lake Crescent are not known, however *Potomopyrgus* spp. (Timms 1978), *Physastra gibbosa* and *Rivisessor gunni* inhabit the lake. At Calverts Lagoon in southeast Tasmania trematode developmental stages conforming to those of *A. gracilis* (Blair 1976) were found in *Coxiella badgerensis* on one occasion (Smith 1981).

The discovery of *A. gracilis* and *D. galaxiae* n.sp. in Tasmania may be cause for concern for local trout fishing and trout farming interests. The specificity of *D. galaxiae* n.sp. at the secondary intermediate host level is unknown, however *A. gracilis* infects rainbow and brown trout in Scotland. These fish are widespread and important in Tasmania. In Scotland, experimentally infected trout of both species were found to have cysts of *A. gracilis* concentrated around the head with a small percentage occurring in the eye (Blair 1976). Further studies are needed to determine the extent of these parasites in Tasmania and whether their intermediate host ranges extend to introduced fish species.

ACKNOWLEDGMENTS

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A BRIEF HISTORY OF LICHENOLOGY IN TASMANIA

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ABSTRACT

KANTVILAS, G., 1983 (31 viii): A brief history of lichenology in Tasmania. *Pap. Proc. R. Soc. Tasm.*, 117: 41-51. ISSN 0080-4703. Department of Botany, University of Tasmania, Hobart, Tasmania, Australia.

The development of lichenology in Tasmania is outlined from the first lichen collections in the late eighteenth century. Special reference is made to the contributions of J.J. Labillardière, Robert Brown, Joseph Hooker, Ferdinand von Mueller and F.R.M. Wilson.

INTRODUCTION

The term 'lichen' literally means eruption or wart. It was first coined in the botanical sense by Theophrastus, a pupil of Aristotle and Plato, who lived in Ancient Greece in 371-284 B.C. (Richardson 1975). Theophrastus included a small number of lichens in his *History of Plants*, one of the earliest botanical treatises known, and a work which earned him the title of 'Father of Botany'. Subsequent references to lichens occur in many European herbals produced during the next 2000 years, a period in which the study of plants centred around their medicinal properties, both real and imagined.

With the development of systematic botany in the late 17th century, lichens were given only scant attention. For example, Linnaeus was no lichenologist despite his achievements in botany as a whole. In fact, he rather despised lichens, calling them 'the poor trash of vegetation' (*rustici pauperrimi*) (Smith 1921). He grudgingly created a solitary genus, *Lichen*, comprising eighty species (Linnaeus 1753). The genus contained seven sections based on growth forms and was grouped with the algae.

Lichenology was established as a separate branch of Botany in 1803 when Erik Acharius, a country doctor from Sweden, published his *Methodus Lichenum*. He elevated the lichens to a separate Order consisting of twenty-eight genera. More importantly, however, he recognised characters that are still used today in lichen taxonomy and devised specialist terminology to describe them.

CONTRIBUTIONS OF THE EARLY EXPLORERS

The earliest published account of an Australian lichen relates to *Baeomyces reteporus* Labill. (now known as *Cladia retipora* (Labill.) Nyl.), collected in Tasmania by Jacques Julien de Labillardière (Labillardière 1807). Labillardière was the botanist and chief scientist on a French expedition commanded by Bruni D'Entrecasteaux in the ships "Recherche" and "Esperance". The French were in Australian waters for nearly four years, including two periods in southeast Tasmania (April 1792 and January 1793). In this time, valuable natural history collections were made, observations of the land and its inhabitants recorded and charts constructed. The expedition suffered an ignominious end, destroyed by disease, mutiny and imprisonment in the Dutch colonies in the Moluccas. However, Labillardière survived and eventually returned to France in 1796. He proved an interesting and fluent writer, producing a general account of the voyage in 1800, *Relation du Voyage à la Recherche de la Pérouse*. His greatest work, however, is his book on the botany of the voyage, *Novae Hollandiae Plantarum Specimen*, published in two parts in 1804 and 1807. The book is the first botanical work devoted to the flora of Australia and Tasmania and describes 265 species. *Baeomyces reteporus* is the only lichen recorded. Its description is in the style of Acharius but since the whole work is arranged according to the system of Linnaeus, *Baeomyces*, together with a liverwort, is classed with the Algae. The collecting locality is given as 'Capite Van Diemen' (= Cape Van Diemen), a general name under which Labillardière lumped all of his Tasmanian collections. (No Cape Van

Diemen exists in Tasmania. Bass Strait was not discovered until 1797 and Labillardière's name probably derives from the idea that Tasmania was a cape of mainland Australia.) The localities he would probably have visited range from Recherche Bay and D'Entrecasteaux Channel to Storm Bay and the Derwent River estuary as far as Glenorchy Rivulet.

Although Labillardière provides the first description of an Australian lichen, it is uncertain whether or not his is the first Australian species to be collected. *Baeomyces reteporus* is listed in *Systema Vegetabilium* (Sprengel 1827) where it is accompanied by a lichen from King Island (*Sticta delisea* Fée) with no acknowledgement of a collector. It also appears in *Synopsis Methodica Lichenum* (Acharius 1814), under the new name of *Cenomyce retipora* (Labill.) Ach., together with another lichen from Australia, *Collema tremelloides* (= *Leptogium tremelloides* (L.fil.) Gray). Acknowledgement for this species is given to Carl Peter Thunberg, a Swedish naturalist who never visited Australia. Although its true collector is unknown, the specimen may have been obtained from Johann Reinhold Forster with whom Thunberg is known to have occasionally exchanged specimens (Hoare 1976). Forster was the naturalist with Captain James Cook's second voyage (1772-1775) in the "Resolution" and the "Adventure". Although the "Resolution" (with Forster on board) did not visit Australia, the "Adventure", commanded by Tobias Furneaux, stopped briefly in Tasmania (at Louisa Bay and Adventure Bay) and very cursory collections of natural history specimens were made (Nelson 1981). When the two vessels were eventually reunited in New Zealand, Furneaux generously gave Forster some zoological specimens he had collected in Tasmania. Nelson (*loc. cit.*) has suggested that Furneaux may have also given some botanical specimens to Forster. If this were true, then Thunberg's lichen may well have been received from Furneaux via Forster and would predate Labillardière's collection by twenty years.

The voyage of D'Entrecasteaux was followed by another French expedition, that of Nicolas Baudin in the ships "Geographe" and "Naturaliste". The expedition was in Australian waters between 1800 and 1804 and, in addition to landfalls on the mainland, explored Tasmania's east coast, D'Entrecasteaux Channel and King Island. Although extensive botanical collections were made by Leschenault de la Tour and his assistant, Guichenot, no comprehensive account of the botany of the voyage was attempted and the existence of any lichen collections is therefore not known.

In 1801, the British Government commissioned the "Investigator", under the command of Matthew Flinders, to undertake a survey of the south coast of Australia. Accompanying the voyage was Robert Brown, a young and energetic botanist from Scotland. Despite a brief anchorage off King Island in Bass Strait, no landfalls were made in Tasmania. However, Brown was later to spend nine months in the state, arriving in 1803 with Lieutenant Bowen and the first settlers on the "Lady Nelson". The settlement at Risdon Cove was established and most of his time was spent there. He also participated in the founding of the settlements at Port Dalrymple (Tamar River) and Sullivans Cove (Hobart). Overall, Brown was unimpressed by the flora of Tasmania:

> "The whole number of plants observed in this port did not much exceed 300, of which about 40 were new to me and, I believe, non-descript."
>
> (from Maiden 1909)

Nevertheless, over half of Brown's lichens were collected in Tasmania and, in view of his comments above, this may have resulted from his lack of enthusiasm for the higher plants of the state.

In 1810, Brown published his *Prodromus Florae Novae Hollandiae et Insulae Van Diemen*, a botanical masterpiece that eclipsed Labillardière's as the flora of the region. It dealt with 4200 plants (3900 from his personal collection) but contained no cryptogams. In the appendix to Flinders' *A Voyage to Terra Australis* (1814) Brown notes:

> "... [the Cryptogams] were not, it must be admitted, equally attended to."

Also in the appendix, he included a list of fifty-eight species of lichen shared by Australia and Europe with the comment that this constitutes about two-thirds of the

diversity. No localities are cited. Although it is said that he planned to publish a more detailed catalogue of lichens (Crombie 1880), this did not eventuate. He died in 1858 and his collection remained in obscurity for twenty years in the British Museum. In 1880, the Reverend James Crombie, a leading British lichenologist, published a catalogue of lichens from Brown's herbarium. It contained 75 species, including 12 descriptions of new lichens, three by Crombie, seven by the French lichenologist, William Nylander, and two by Brown himself that had been found in his notes. Forty-two of these lichens are from Tasmania, the localities being "Derwent River", "Table Mt. (= Mount Wellington) and its foothills" and "Risdon Cove". The localities, however, should be treated with extreme caution. Two of the new species from Mount Wellington, Tasmania, *Parmelia australiensis* Crombie and *Chondropsis semiviridis* F. Muell. ex Nyl., have never since been reported from Tasmania. Both are found along the arid coast of the Great Australian Bight so it seems quite likely that either Brown or Crombie muddled their labels (see Paulson 1930 and Filson 1976).

THE EARLY COLONIAL PERIOD

Contributions of the English

With the establishment and growth of the Australian colonies, the main thrust of botanical exploration shifted from the sea-faring botanist confined to the coast, to the resident with access to the inland. Sir Joseph Banks, who had previously ensured that botanists accompanied the British voyages of discovery, began to send collectors to the colonies or to recruit the settlers themselves. Banks' first envoy was George Caley who visited Tasmania briefly in 1805 but did not collect any lichens. His successor was Alan Cunningham who achieved fame not only as a botanist but also as an explorer. He visited Tasmania in 1818 aboard the "Mermaid" whilst on a survey of the coasts of Australia with Philip Parker King. Macquarie Harbour, Hobart and Mount Wellington were visited. The only Tasmanian lichen known in his collection is *Cladonia rangifera* (L.) Web. (mistakenly cited as *C. rangiferina* Hoffm. in Babington & Mitten 1860).

With the death of Banks in 1820, the task of corresponding with the Australian colonies fell to William Jackson Hooker. Hooker tried to establish correspondence with someone in Tasmania but initially without success. At length, in 1827, he received his first favourable reply, from Thomas Scott, a merchant of Launceston. Scott was at best a very reluctant collector. His correspondence was sporadic and his gatherings scanty, usually of seeds. He has earned his place in this discussion not for any contribution to lichenology but because he was the first of a long line of Tasmanian collectors. His most important letter to Hooker came in 1830, when he introduced Robert William Lawrence as a prospective collector for Kew:

> "... he is a young man, very anxious to learn and I have no doubt but you will find him a very valuable correspondent."
>
> (from Burns & Skemp 1961)

Son of William Effingham Lawrence, a wealthy landowner of Launceston, Robert Lawrence was a man of leisure. Unlike Scott, he had an avid interest in science, devoting much of his spare time to botany. In his first meek letter to Hooker he wrote:

> "My knowledge of this science [i.e. Botany] is certainly very slight indeed, I am a mere learner ... but I hope that in time, by application, I shall become as much of a Botanist as to enable me to be useful to you if you will accept my services such as they may be."
>
> (Burns & Skemp 1961)

To learn in a remote place like Tasmania must have been an arduous task. He had no books, nor paper, nor colleagues with whom to discuss his work, and his only advisor was thousands of miles away. Nevertheless, each shipment of specimens, and these included many lichens, was rewarded with gifts of books and encouragement from Hooker.

Lawrence was not alone in his pursuit of botany for long. Through the social life of Launceston, he met a young man of his own age and outlook, Ronald Campbell Gunn. Born in South Africa, Gunn had been educated towards a military career in Scotland. He migrated to Tasmania on the advice of his brother and obtained employment as a superintendent of convicts in Hobart. He was ambitious and hardworking, and in the short space of three years he was promoted to a Police Magistrate in Launceston, in control of all the convicts in northern Tasmania. Gunn and Lawrence became great friends and soon Lawrence, echoing the words of Scott a few years earlier, was writing to Hooker:

> "Give me leave to introduce to you my friend Mr. Gunn, a gentleman who has lately acquired a passionate taste for the science of Botany and who has become an enthusiastic collector."
>
> (Burns & Skemp 1961)

With Hooker's guidance, they devoted their energies to science and the pursuit of knowledge. Unfortunately, their close friendship was cut short in 1833 by the tragic death of Lawrence on his twenty-sixth birthday. Gunn was shattered, but not even the death of his friend and colleague could deter him from his new interest. He wrote to Hooker:

> "His loss to you will be most severe, as he was years ahead of me in experience, both of Botany and the localities of the plants of Van Diemen's Land - I can only, however, promise to do all I can and trust that time will improve me."
>
> (Burns & Skemp 1961)

The work of responsible correspondents such as Lawrence and Gunn proved invaluable to William Hooker (and others) in England whose studies on the Australian flora relied completely on the receipt of adequate specimens from the colonies. Hooker's links with Tasmania were strengthened with the arrival in Hobart of his son, Joseph Dalton Hooker, in 1840. He accompanied an expedition commanded by Sir James Clarke Ross in the ships "Erebus" and "Terror". Although Joseph Hooker was employed as assistant surgeon aboard the "Erebus", he was an adept botanist, as was David Lyall, his counterpart on the "Terror". The aim of the voyage was to study terrestrial magnetism, but due to the enthusiasm and expertise of its members the greatest contributions proved to be in natural history. The ships arrived in Hobart on 16th August 1840 via the Cape of Good Hope and Kerguelen Island. The botanists rapidly made their acquaintance of Gunn and in the course of their three-month stay collected in the Derwent and Clyde Valleys, the Central Plateau and Port Arthur. After spending that summer in Antarctic waters, they returned to Hobart on 7th April 1841 for another three-month sojourn. This time collections were made from the Huon Valley and the Richmond area. Inevitably, Joseph Hooker and Ronald Gunn became close friends and later Hooker wrote:

> "... [I] am indebted to him for nearly all I know of the vegetation of the districts I visited. I can recall no happier weeks of my various wanderings over the globe than those spent with Mr Gunn, collecting in the Tasmanian mountains and forests, or studying our plants in his library."
>
> (Hooker 1860)

Three years in all, between 1839 and 1842, were spent in southern waters, visiting Tasmania, New Zealand, Antarctica, the subantarctic islands and southernmost South America. An enormous collection, consisting of marine animals as well as plants, had been amassed in that time. Largely at the insistence of his father, Joseph Hooker embarked on the ambitious project of writing an account of the botany of the regions he visited.

Although he was one of the more promising English botanists of the time, Joseph Hooker was not an accomplished lichenologist. For the study of this group he secured the assistance of Thomas Taylor, Professor of Botany at Cork and an expert on lichens, mosses and liverworts. In 1844, they published a catalogue of 151 lichens collected on the voyage Fifty-four of these were new species, eleven from Tasmania (Hooker & Taylor 1844). In the same year, the first part of J.D. Hooker's *Botany of the Antarctic Voyage* (i.e. *Flora*

Antarctica, Vol. I) appeared, containing a section on lichens by Taylor and Hooker. Taylor published additional contributions alone, including the description of two mainland species from Alan Cunningham's lichen collection (Taylor 1844). In the description of one of these species, Taylor acknowledges a specimen from Tasmania collected by Dr Balfour. Another publication followed in 1847 describing three new Tasmanian species. The source of these in "Mr. Borrer's herbarium" (Taylor 1847). However, William Borrer, a renowned British botanist and lichenologist, never visited Tasmania, so the true collector of these lichens is unknown, although Wetmore (1963) infers that they were collected by Lawrence. Taylor died in 1848 and subsequent studies on the lichens from the voyage were undertaken by the Reverend Churchill Babington who, in addition to his botanical pursuits, was also Professor of Archaeology at Cambridge.

1860 saw the publication of *Flora Tasmaniae*, part 3 of J.D. Hooker's *Botany of the Antarctic Voyage* and a landmark in the history of Tasmanian botany. The work was dedicated to Ronald Campbell Gunn and William Archer, a friend of Hooker, "for their indefatigable exertions" (Hooker 1860). The colonial government of Tasmania contributed £350 towards publication costs, supplementing £1000 provided by the British Government Treasury. A further £100 was donated by Archer. The work, dealing with angiosperms, gymnosperms, pteridophytes, bryophytes, algae, lichens and fungi, was the first attempt to document the total flora of Tasmania, a feat which has never since been repeated despite subsequent revisions of selected plant groups.

The lichen section of *Flora Tasmaniae* was written by Babington, with assistance from William Mitten with the crustose species. Mitten was a young bryologist who had risen to prominence with the death of Taylor. All in all, 93 lichens were enumerated, two of which were described as new (*Sticta cetrarioides* Bab. [= *Heterodea muelleri* (Hampe) Nyl.] and *Baeomyces heteromorphus* Nyl.). Specimens from a variety of sources were acknowledged. These included the collections of Lawrence and Gunn, as well as the vast herbarium amassed by Hooker and Lyall on the Antarctic voyage. In addition, many specimens were obtained from Archer who was an enthusiastic plant collector. Born in Launceston and educated in England, Archer lived on his estate, "Cheshunt", near Deloraine. He practised as an architect, designing the old Hutchins School in Hobart and other buildings. He was also a painter and his works include the orchid plates for the *Flora Tasmaniae*.

Further specimens for the *Flora* had been provided by Ferdinand von Mueller. Mueller had emigrated from Germany in 1847 and had settled in Adelaide where he worked as a pharmacist. His chief interest, however, was botany and he spent much of his spare time collecting and exploring. He established correspondence with William Hooker at Kew as well as with numerous other botanists, both abroad and in the Australian colonies. One of his first Tasmanian contacts was Charles Stuart whom he met in Adelaide in 1847. Stuart had collected for Gunn whilst working as a nurseryman in Tasmania. Evidently, however, the two had fallen out. In a letter to Mueller he wrote:

> "Respecting the specimens left with Mr. Gunn, he has in a most unhandsome manner made away with them, and then made a paltry excuse, saying he thought I should not need them ... but after the number of specimens I have given him, and information he has got from me, I should not have thought him so bad, but the fact is he is jealous of any person's knowledge of plants lest it should discover his defects."
>
> (Daley 1935)

Mueller befriended Stuart who, on returning to Tasmania, began to send plant specimens to him. Mueller also obtained Tasmanian plants from Augustus Oldfield, a botanist and explorer who collected in Western Australia and New South Wales as well as in Tasmania. The collections of Stuart and Oldfield contained many lichens, some of which were placed at the disposal of Babington and Mitten for the *Flora*. Additional small contributions of specimens were obtained from the herbaria of Alan Cunningham, from Samual Mossman, a traveller who collected and sold botanical specimens and from the European lichenologist, Elias Fries. The latter never collected in Australia though he did have access to Australian collections (Wilson 1890). The source of his Tasmanian lichen is unknown.

Brief History of Lichenology in Tasmania

Contributions of the French

Although the Antarctic voyage of the "Erebus" and "Terror" ranks supreme in terms of botanical exploration in the southern zone, it was by no means a unique venture. A similar expedition was undertaken almost simultaneously by the French under the command of Dumont D'Urville. Although the achievements of this voyage are less well known than those of the English, they are by no means insignificant. D'Urville was no stranger to Australian waters. He had visited Sydney in 1824 as a botanist aboard the "Coquille" commanded by Duperrey. In 1827, he visited Hobart in command of his own vessel, the "Astrolabe". Although the botanical results of the expedition, published by Achille Richard and A. Lesson, deal largely with New Zealand, some Tasmanian lichens are also included (Lesson & Richard 1832). This expedition was followed by a voyage to Antarctica in the "Astrolabe" and "Zélée", lasting from 1837 to 1840. The voyage parallels that of Hooker, particularly in its study of terrestrial magnetism. Botanical collections were undertaken by Hombron, the surgeon, Jacquinot, the second-in-command and D'Urville himself. After a tortuous voyage through the Indian Ocean, the expedition limped into Hobart in December 1839. Dysentry and fever had ravaged their numbers and the time in port was spent in burying the dead and recuperating. From Hobart they sailed to Antarctica, discovering and claiming Adélie Land for France. The expedition returned to Tasmania in February 1840. Although D'Urville's time in Tasmania was short, he was well received and spent some time travelling, visiting Launceston and the midlands and climbing Mt Wellington. The *Hobart Town Courier* carried an account of his travels and an expression of his thanks to the people of Tasmania (see Triebel & Batt 1957).

The botanical results of the expedition were published by Hombron & Jacquinot in 1845. In many respects the work overlapped with Joseph Hooker's *Botany of the Antarctic Voyage*. However, Hooker himself seemed unimpressed with the French work:

> "They have published very few of my best plants, not my best at all, I am happy to say - their figures are very poor indeed and the depictions miserable."
>
> (Hooker to Gunn 1844, from Moyal 1976)

The cryptogamic plants were studied by the French lichenologist, Camille Montagne. His account of the lichens (Montagne 1845) lists species from the Pacific, the Straits of Magellan and New Zealand, as well as two species from Tasmania (*Usnea florida* Hoffm. and *Cladonia furcata* var. *pungens* Floerke) collected at Hobart by Hombron. Montagne's work also contains one of the earliest accounts of the similarities in the lichen floras of the northern and southern circumpolar regions.

THE LATE NINETEENTH CENTURY

By the middle of the nineteenth century a core of enthusiastic scientists had organised themselves in Tasmania. Personal visits by men of the calibre of Joseph Hooker had instilled encouragement and expertise in local botanists who in turn shared their knowledge with colleagues. Other visitors included Professor William Harvey from Dublin. A renowned phycologist, Harvey arrived in Tasmania in 1855 and rapidly established a network of algae collectors. However, his activities were apparently not restricted to the algae for a lichen from his Tasmanian collection, gathered jointly with Mr W.H. Ince, is mentioned in Cheel (1924).

Ferdinand von Mueller, now based in Melbourne, had emerged as one of Australia's most accomplished botanists and had established a large network of collectors. In Tasmania, Charles Stuart remained his most active lichen collector and many of Stuart's lichens were forwarded to Dr E. Hampe in Germany. Hampe published a catalogue containing thirty-six Tasmanian lichens (Hampe 1852) including two new species, *Lecidea stuartii* Hampe and *Biatora byssacea* Hampe. Mueller received other Tasmanian lichens from collectors such as T.A. and B. Gulliver (who collected mainly on Mt Wellington), from Skelton Emmett (Circular Head), from Ambrose Neale (King Island) and from Dr George Fordyce Story, surgeon at Waterloo Point Military Station near Swansea. These collections were sent to Anton von Krempelhuber in Munich (Krempelhuber 1881). Krempelhuber was no stranger to Australasian

lichens, having studied the collections of Karl von Hügel who had toured the world between 1831 and 1837. Most of Hügel's time in Australia in 1833 was spent at the Swan River Colony in Western Australia, although Krempelhuber (1868) attributes a few Tasmanian collections to him. Through his experience with Australian material, Krempelhuber was able to assist Mueller in compiling a list of lichens for his *Fragmenta Phytographiae Australiae* (1858-81) (Krempelhuber 1880).

Meanwhile in Geneva, much of the nomenclature of Australasian lichens was being revised by Dr Jean Müller in a series of publications dating from about 1878. This work included Tasmanian lichens from many earlier collections (Müller 1882a, 1882b, 1883, 1889) as well as a revision of Krempelhuber's work (Müller 1887). Müller also corresponded with Ferdinand von Mueller from whom he received lichen material including occasional specimens from Tasmania which Mueller had collected himself. Wetmore (1963) erroneously lists Amalie Dietrich and Franz Sieber as collectors of Tasmanian lichens published by Müller and Krempelhuber. Neither of these two collectors ever visited Tasmania. Sieber's specimen from "Mt. Wellington" is not from the Tasmanian peak of that name.

Additional studies on Tasmania's lichen flora were undertaken by Dr James Stirton, lecturer in gynaecology and Professor of Midwifery at Glasgow, Scotland. He devoted himself to the study of mosses and lichens, paying particular attention to the flora of Scotland. Later he received material from all over the world, including Tasmania, New Zealand, Australia, Canada, South America and South Africa (Trail 1917). The majority of his Tasmanian lichens were collected by Hugh Paton of Glasgow who toured Australia some time prior to 1880. Other Tasmanian specimens were obtained from Walter Campbell, an inspector of agriculture in New South Wales and part-time collector for Ferdinand von Mueller, from Mrs Heywood McEwen and from E. Spong of King Island. All in all, Stirton described eight new species from Tasmania (Stirton 1876, 1882, 1898, 1900).

Up to this point, the history of Tasmanian lichenology has been a saga of the sporadic export of Tasmanian specimens for study by overseas experts. In fact, in the years following the publication of Hooker's *Flora Tasmaniae*, hailed as "the foundation of the whole cryptogamic botany of Australia" (Mueller 1881), there had been a gradual waning of interest in lichenology in Tasmania. In 1881, Ferdinand von Mueller appealed for someone to collect and study Tasmanian cryptogamic plants:

> "It may be predicted with confidence that the number of mosses, lichens and algae of Tasmania will be still considerably augmented by assiduous and perservering searches."
>
> (Mueller 1881)

In spite of Mueller's plea, local interest and expertise with Tasmanian cryptogams, especially lichens, was slow to develop. However, in 1884, the Royal Society of Tasmania gained three new members, all of whom were to make a significant contribution to bryology and/or lichenology. Nevertheless, none was to actually publish any lichenological works relevant to Tasmania. They were Richard Austin Bastow, William Anderson Weymouth and Leonard Rodway.

Richard Bastow arrived in Tasmania in 1884 from Manchester where he had been a sanitary surveyor. He began to study lichens and bryophytes, collecting over a wide area throughout Tasmania. He was a qualified architect and soon put these skills to use in illustrating his publications with excellent line drawings. Assisted by his friend, Mr C.J. Atkins, he often displayed labelled exhibits at meetings of the Royal Society. Unfortunately, his published works did not extend to Tasmanian lichens and although he was a true pioneer in developing a local lichenological following in Tasmania, he is best remembered today for his accounts of the mosses and liverworts (the first since those of Hooker in *Flora Tasmaniae*). In 1888, he moved to Melbourne where his attention turned to the Victorian flora.

In contrast to Bastow, Weymouth was a second generation Tasmanian living in Hobart. He was a prodigious collector of bryophytes and lichens, a hobby he adopted in 1887. Occasionally accompanied by his friend, the Reverend John Bufton, his collecting took him

as far afield as Mt Bischoff and Mt Lyell on the west coast, Circular Head, Tasman Peninsula and Mt Arthur near Launceston. He corresponded with and sent specimens to numerous overseas experts and a catalogue of sixty-three lichens collected by him was published in Italy by Jatta. Ten new species, including *Ochrolechia weymouthii* Jatta, and three new varieties were described (Jatta 1910). Like Bastow, Weymouth's greatest contribution to Tasmanian botany was in the field of bryology. Although he was working towards a bryophyte flora of Tasmania, the final work was undertaken by Leonard Rodway in 1912. Rodway became the greatest Tasmanian botanist of the time and author of more than fifty works, including the *Flora of Tasmania* in 1903. Although he made occasional collections of lichens (Cheel 1912, 1914) they proved to be one of the few plant groups he did not study in detail.

Despite the large collection of lichens amassed by Bastow and Weymouth, it was left to mainland lichenologists to make the greatest contributions to Tasmanian lichenology. Prior to his move to Melbourne, Bastow had hoped to describe the lichen flora of the island but this work had been abandoned. Instead he passed the project and his collection to his good friend, the Reverend Francis Robert Muter Wilson, a Presbyterian minister stationed at Kew in Melbourne. Wilson was Australia's most productive lichenologist. He maintained active correspondence with European specialists such as Jean Müller but he also published a great deal of his own work in a series of about twenty papers (Filson 1976) between 1887 and his death in 1903. In the early 1890's he visited Tasmania, collecting at Launceston and Mt Arthur, St Marys Pass, Ulverstone, Hobart and Mt Wellington and the Huon River. He also made the acquaintance of local Tasmanian naturalists, notably Weymouth in Hobart and Augustus Simson, the founder and secretary of the Northern Tasmanian Natural Science Association in Launceston. Simson had arrived in Tasmania in 1873 and moved to Launceston in 1879, where he ran a stockbroking business in partnership with his brother. His lichen collections were mostly from Mt Wellington, the Blue Tier and Georges Bay. Wilson was given access to both Simson and Weymouth's private herbaria. He also obtained specimens from Miss Lilley (of Launceston) and a person called Coates, as well as some lichens from the Gordon River collected by Morton Allport. Allport, who died in 1878, was a lawyer, naturalist and bushwalker and was generally regarded as one of the most successful locally educated figures of the time.

In 1893, Wilson published a list of 151 Tasmanian lichens based on his own collections and those of the Tasmanian naturalists listed above, as well as on the lichen section in *Flora Tasmaniae* (Wilson 1893). In addition, he acknowledged a single gathering by Jules P. Verreaux (previously examined in France by Nylander in 1860) who had visited Tasmania between 1842 and 1847 as a collector for the Museum of Natural History in Paris. Wilson updated much of the earlier work on Tasmanian lichens and included brief descriptions of all the species. This paper remains the most comprehensive account of the Tasmanian lichen flora to this day.

In addition to Wilson, another prominent lichenologist, John Shirley, had emerged in Australia. Shirley had emigrated to Queensland in 1878, after receiving his B.Sc. in London as a student of the famous Thomas Huxley. In Queensland he worked first as a teacher and then as a school inspector, a job which enabled him to travel widely and nurture his broad interests in biology and geology. However, it was in lichenology that he particularly excelled and his studies led to the publication of the *Lichen Flora of Queensland* in 1888-89. He visited Tasmania in 1892 for a meeting of the Australasian Association for the Advancement of Science, during which time he collected at Mt Wellington. He also met Weymouth who had presented a paper on the bryophytes of Tasmania to the meeting and who gave him a selection of lichen specimens from his herbarium. Shirley's first contribution to Tasmanian lichenology was a catalogue to 158 species based on virtually all of the early literature (Shirley 1893). The following year he produced an additional list of fifty-five lichens based on his own and Weymouth's collections (Shirley 1894). Seven new species were described, including *Patellaria weymouthii* Shirley. In 1912, Shirley gained a D.Sc. from the University of Sydney for a thesis entitled *"The Thallus of the Genus Parmelia"*. It is of some interest that this celebrated work was subsequently published in Tasmania by the Royal Society (Shirley 1918).

THE TWENTIETH CENTURY

The dawn of the twentieth century saw the death of Wilson and the subsequent decline of lichenology both in Tasmania and Australia. Australian lichenology as a whole sustained a great tragedy with the loss of a crate of Wilson's type specimens en route to Italy in 1907 (see Filson 1976). In Tasmania, the void left by Bastow and Weymouth remained unfilled and although occasional isolated collections were still made, there was no systematic, large-scale lichen collecting undertaken. A small number of specimens found their way into overseas publications. Gustav Weindorfer, an Austrian-born naturalist living at Waldheim, Cradle Mountain, sent lichens to Zahlbruckner who described the new species *Menegazzia weindorferi* Zahlbr. from Mt Roland in his honour (Zahlbruckner 1906). The British botanist, Lilian Suzette Gibbs collected Tasmanian lichens during her visit in 1914 (Gibbs 1920, Wetmore 1963). Still other collections, however, were left unstudied, a fate destined for F.E. Burbury's collection from northeast Tasmania made between 1880 and 1920, and now lodged in the Tasmanian Herbarium.

A small nucleus of lichenological activity in Australia centred around Edwin Cheel at the National Herbarium in Sydney. After humble beginnings, first as a farm labourer in Queensland and later as a gardener at Centennial Park in Sydney, Cheel became an expert in cryptogamic plants, largely through the encouragement of Joseph Henry Maiden. In 1901, he was placed in charge of the lichens at the National Herbarium and was promoted to Curator in 1924. He received many Tasmanian lichens and numerous minor collections are cited by him in his largely bibliographic publications (see Cheel 1912, 1914, 1924). His collectors included the algologist A.H.S. Lucas (collections from Mt Wellington and the Hartz Mts), J.H. Maiden and the writer and artist, Caroline Louisa Waring Atkinson (collections from Waratah).

In 1963, Clifford Wetmore in the U.S.A. published a catalogue of Tasmanian lichens, drawing together into a single paper all the literature concerning the lichen flora of the island. He also included a directory of collectors and the location of their collections. Although no taxonomic revision was attempted, Wetmore (1963) expressed the hope that this would be prompted by his paper. No such work, however, has yet eventuated.

In May 1974, at a meeting held at the National Herbarium in Melbourne, the Australasian Association for Lichenology was formed in response to a renewed interest in lichens and with the intention of charting the future course of Australian lichenology. One of the founding members was a Tasmanian, Geoffrey Charles Bratt. A graduate of the University of Tasmania, Bratt gained his Doctorate in Chemistry at the University of London. His interest in lichens began in 1958 whilst on a glaciological expedition to Patagonia. He returned to Tasmania in 1959 to work as a research chemist at the Electrolytic Zinc Company. A keen bushwalker and mountaineer, he turned these skills towards lichen collecting and amassed what is undoubtedly the most extensive collection of Tasmanian lichens. Many specimens were sent overseas to numerous experts, one of whom, Theodore Esslinger, named the New Zealand endemic species *Parmelia brattii* in his honour. Bratt wrote a number of short papers on the Tasmanian lichen flora but his work ended abruptly in 1977 with his untimely death. His collection, amounting to 15 000 specimens, is lodged in the Tasmanian Herbarium.

Despite the loss of this great collector, Tasmanian lichenology has not languished. Recent visits by overseas specialists have inspired continued interest in Tasmanian lichens, ensuring that lichenology will no longer be the neglected aspect of natural history in Tasmania.

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(ms. received 18.5.1982)

AN UNUSUAL OCCURRENCE OF ULTRAMAFIC AND MAFIC ROCKS NORTH OF MT BISCHOFF, NW TASMANIA

by P.R. Williams and A.V. Brown
Geological Survey of Tasmania

(with one table and one text-figure)

ABSTRACT

WILLIAMS, P.R. & BROWN, A.V., 1983 (31 viii): An unusual occurrence of ultramafic and mafic rocks north of Mt Bischoff, NW Tasmania. *Pap. Proc. R. Soc. Tasm.*, 117: 53-58. ISSN 0080-4703. Department of Mines, Bligh Street, Rosny Park, Tasmania, Australia.

Plagioclase-bearing harzburgite, plagioclase lherzolite, basalt and dolerite intrude a sequence of mudstone, greywacke, pillowed basalt and chert in the Arthur River valley north of Mt Bischoff. The ultramafic rocks are concordant bodies characterised by absence of internal deformation structures, abundant primary mineral assemblages and cumulate textures. The ultramafics were most probably intruded as magma. Fine- to coarse-grained dolerite were intruded in the same zone, probably as dykes.

The dolerite is chemically and texturally distinct from pillowed basalt interbedded with the sedimentary sequence.

INTRODUCTION

Outcrops of ultramafic and mafic rocks in the Arthur River valley north of Mt Bischoff (fig. 1) were mapped during the Geological Survey of Tasmania's coverage of the St Valentine Quadrangle in northwestern Tasmania. The occurrence was previously unrecorded, as was much of the sedimentary and volcanic sequence of the surrounding countryside. The ultramafic rock bodies are unusual to Tasmania, in that they are apparently undeformed, display their primary mineral compositions without extensive serpentinization and appear to intrude the surrounding sedimentary/volcanic sequence as sills. A distinctive doleritic rock type intrudes the sedimentary/volcanic sequence in the same area as the ultramafic rocks. The purpose of this paper is to describe and contrast the igneous rock types in this unusual occurrence, and to compare the ultramafic rocks with those elsewhere in western Tasmania.

GEOLOGICAL SETTING

The area is underlain by a sequence of probable Eo-Cambrian or Early Cambrian greywacke, mudstone, basaltic lava, and subsidiary chert. These overlie the Proterozoic Mt Bischoff sequence with unconformity (Groves 1971). The proportion of mudstone, chert and greywacke to basaltic lavas varies considerably, and in places greywacke is absent and lava flows are separated by thin mudstone beds and minor chert. In the region of ultramafic rocks there is an approximately equal abundance of greywacke and mudstone, with more chert than usual and less basaltic lava. The sequence is continuous with the rock exposed in the Cleveland mine area (Cox and Glasson 1971; Collins 1981). The greywacke from the sequence in the Arthur River is very poorly sorted, composed of angular grains of feldspar, quartz and rock fragments. The rock fragments are metaquartzite, similar to quartzite from the Tyennan region metamorphic rocks of central Tasmania. The presence of detrital garnet grains as well as metaquartzite suggests a Tyennan source area. Garnet has not been reported from Proterozoic rocks in northwestern Tasmania. Detrital muscovite and biotite are also present. Chert interbedded with the mudstone and greywacke is usually finely-laminated often with well-preserved fine undulations, suggesting that it is a

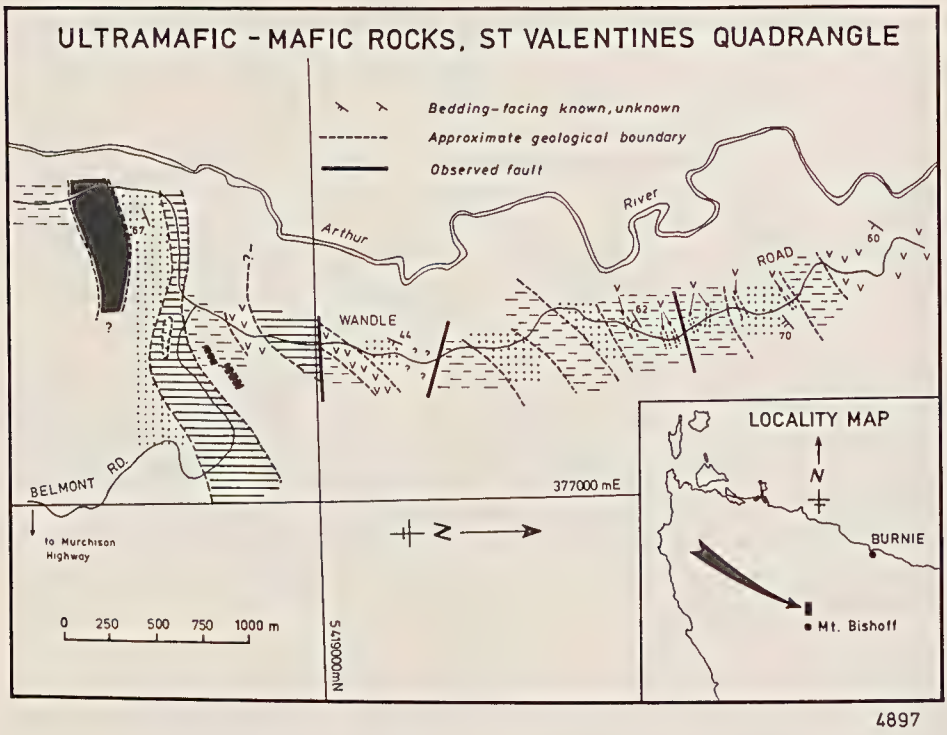

FIG. 1. - Geological map of the area around Belmont Road and Wandle Road in the Arthur River valley. Horizontal dashes indicate mudstone, dots indicate greywacke and chert, v's indicate pillowed basalt, heavy horizontal lines indicate intrusive basalt and dolerite, and black areas indicate ultramafic rocks. Inset map shows location of the area, accessible via Belmont Road from the Murchison Highway.

primary deposit. There is no evidence of detrital grains, implying that the chert may have been a chemical sediment.

BASALTIC ROCKS INTERBEDDED WITH THE SEDIMENTARY SEQUENCE

Basaltic rocks in the sequence increase in abundance to the north. The basalts form pillow structures (Groves and Solomon 1964) and several exposures of pillow structure are observable on new Forestry roads in the area. Cusps of pillows are often filled with chert. In addition basaltic lapilli tuff is present, composed of rounded fragments of basalt in a fine-grained dark-coloured matrix with abundant pyroxene crystals (crystal lithic lapilli tuff). The basalt is typically an equigranular or porphyritic rock with small phenocrysts of plagioclase and pyroxene in a matrix of feldspar laths, pyroxene crystals and chlorite showing an intersertal texture. The mineralogy and texture of these rocks has been described in detail by Groves and Solomon (1964). Chemical analyses of the basalt and tuff are shown in table 1 (analyses 1-4).

TABLE 1

CHEMICAL ANALYSES

	1 783165*	2 814513	3 783164	4 814514	5 814515	6 814512	7 783163	8 814511	9 813140	10 814510	11 814507	12 814508
SiO_2	46.6	47.44	50.0	47.80	50.97	49.55	50.3	52.69	38.48	38.64	40.38	40.84
TiO_2	1.7	3.38	1.0	1.95	0.25	0.39	0.39	0.55	0.03	0.03	0.04	0.05
Al_2O_3	14.2	12.31	13.3	13.26	13.56	14.15	14.0	13.26	4.41	4.34	5.42	5.40
Fe_2O_3	3.3	9.15	2.5	3.09	3.55	3.78	3.1	5.54	5.23	3.47	3.12	3.02
FeO	9.2	4.67	8.0	9.68	7.41	7.10	6.9	7.41	5.28	5.51	5.81	6.49
MnO	0.22	0.27	0.19	0.18	0.18	0.18	0.20	0.19	0.15	0.16	0.17	0.16
MgO	7.5	5.54	8.2	6.34	6.79	7.55	7.7	5.00	31.89	32.94	31.04	32.42
CaO	9.7	7.89	9.1	8.83	10.27	8.65	8.6	6.34	4.26	4.05	4.11	4.15
Na_2O	2.8	3.39	2.2	3.33	3.83	2.82	3.7	5.18	<0.03	0.10	0.07	0.21
K_2O	1.0	0.86	0.53	0.22	0.34	0.21	0.28	0.17	0.03	0.07	0.06	0.07
P_2O_5	0.07	0.36	0.16	0.21	0.05	0.06	0.03	0.07	0.01	0.02	0.02	0.03
Loss	4.06	3.67	4.80	4.10	3.37	4.77	4.60	2.65	9.86	9.68	8.87	6.62
Cr	171	146	289	153	81	295	258	81	3698	4249	4903	4363
Ni	103	79	106	92	73	104	119	63	1621	1703	1616	1657
Rb	20	8	12	4	10	5	4	<4	<4	<4	4	6
Sr	484	288	147	222	107	171	226	210	27	15	21	28
Y	22	33	25	20	8	14	15	18	<4	<4	<4	<4
Zr	111	216	80	111	9	17	<5	22	4	<4	<4	<4
Mg	52	43	59	47	55	56	59	42	85	87	87	86
Ti/Zr	92	94	75	105	166	317	468	150	45	45	60	75
Ti/Y	463	614	240	585	187	39	156	183	45	45	60	75
Zr/Y	5.05	6.55	3.2	5.55	1.13	1.21	0.33	1.22	1	1	1	1
Cr/Ni	1.66	1.85	2.73	1.66	1.11	2.49	2.17	1.29	2.28	2.50	2.53	2.63

Analyses 1-4: Basaltic rocks from within the sedimentary sequence.
5-8: Fine-grained intrusive rocks.
9-10: Ultramafic body, Wandle Road.
11-12: Ultramafic body, Belmont Road.

* Sample numbers - Department of Mines analytical numbers.
Analysts: J. Furst and R. Roby, Department of Mines Laboratories, Launceston.

Ultramafic and Mafic Rocks North of Mt Bischoff

INTRUSIVE ROCKS

Near the intersection of Belmont Road and Wandle Road, two major intrusions of ultramafic rock and one major intrusion of mafic (doleritic) rock have been identified (figure 1). In addition there are several intrusions or extrusions of basalt between the two ultramafic bodies. The mafic and ultramafic rocks occur in the same zone, but no age relationship between them has been observed. The southern ultramafic body is regionally concordant, and where contacts with sedimentary rocks are exposed these parallel bedding. However, the northern ultramafic body has a faulted northern margin, and the surrounding mudstone is highly fractured. These fractures are filled with quartz and very iron-rich chlorite (with second order birefringence colours) and post-date cleavage. The fault is inferred to be Devonian in age, because the cleavage probably formed during a Devonian deformation event.

On the southern edge of the southern ultramafic body there is a sequence of graded contact metamorphosed greywacke beds with pelitic tops. The pelitic tops are spotted, and the spots are deformed into lozenges parallel to cleavage, implying that metamorphism occurred prior to deformation. There are no nearby dolerite dykes or pillow lavas. The metamorphism of the country rock, and absence of any deformation features suggesting solid state movement in the ultramafics is used to infer that the ultramafics intruded as a liquid-dominated magma. However, poor exposure away from road sections does not allow a metamorphic aureole to be mapped out. The spotting and grading define the sedimentary facing of the sequence, which is to the north in this area.

In the area between the two major ultramafic bodies smaller intrusions of ultramafic rock (about 30 m thick) are concordant with a sequence of indurated chert and mudstone with incipient metamorphic spotting and biotite development. The sequence includes basalt with mudstone xenoliths. The sedimentary rocks have been brecciated and the fractures filled with opaque minerals.

The weight of evidence, therefore, strongly suggests that the ultramafic rocks were intruded as magma into the chert-greywacke-mudstone-pillowed basalt sequence. Later faulting has occurred along some primary boundaries, but other boundaries are undisturbed.

Mafic rocks have also been intruded into the sedimentary sequence (figure 1). The body of dolerite south of the ultramafic rocks cross-cuts the chert sequence in that area at a low angle. Several small areas of porphyritic, fine- and medium-grained dolerite occur in the area between the two ultramafic intrusions and one large outcrop has a discordant boundary. At one of these localities fine-grained dolerite, in continuity with the medium-grained dolerite, may represent a chilled margin. They are inferred to be dykes, although the possibility that some may be sills cannot be ruled out. The age relationship between the dolerite and ultramafic rocks cannot be determined, although intruded into the same area.

The intrusive rocks range in texture from basaltic, with a grainsize of about 0.02 mm, up to doleritic rocks, with a grainsize of about 2 mm. Rare gabbroic rocks are present. The basaltic rocks are composed of patches of chlorite, large pyrite grains, abundant small anhedral grains of pyroxene which tend to aggregate in patches in a matrix of altered laths of plagioclase. These are much more altered rocks than the basalt interbedded with the sedimentary rocks, and the presence of fine-grained granular aggregates of small pyroxene grains has not been observed in the pillowed basalt. Rare altered feldspar phenocrysts (plagioclase) are present and rare augite posettes also occur. Very fine-grained rocks contain abundant phenocrysts of plagioclase. Some calcite veins are also present.

In contrast the coarse-grained intrusive varieties contain subhedral augite crystals in a matrix of truncated feldspar laths (intergranular texture). Large chlorite phenocrysts with prismatic habit are clearly pseudomorphs after another ferro-magnesian mineral. Other specimens tend to ophitic to sub-ophitic and tremolite occurs as fibrous aggregates in anhedral patches. Rocks of intermediate grainsize show near anhedral pyroxene.

Very altered specimens are common and are composed dominantly of chlorite and feldspar (albite) with abundant opaque minerals. The rocks exhibit thick tremolite veins, fresh albite veins and sericitic patches. The absence of this type of alteration in the basaltic lava flows in the sedimentary rocks suggests that it may be primary or deuteric alteration. Chemical analyses of these mafic rocks are shown in table 1 (analyses 5-8).

The ultramafic bodies grade from plagioclase and clinopyroxene bearing granular harzburgite at the top of the bodies to plagioclase bearing poikilitic lherzolite at the base. Overall the bodies are massive with little grainsize variation. The bases are coarser than the tops and contain a larger percentage of euhedral crystals.

Olivine and accessory chrome spinel are the cumulate mineral phases while pyroxene and plagioclase are post-cumulate. No indication of layering or of mineral fabric (foliation) is seen. The distribution of plagioclase is irregular. In places, olivine crystals are mantled by mesh serpentine group minerals and outlined by fine-grained magnetite. Interstitial highly altered plagioclase usually forms as cuspate patches but occasional fresh subhedral grains are seen.

In the northern part of the largest body, exposed along Wandle Road, the plagioclase-bearing harzburgite has a panidiomorphic granular texture of rounded olivine and euhedral chrome spinel grains surrounded by anhedral post-cumulate granular orthopyroxene with minor irregular patches of clinopyroxene and plagioclase. Olivine and orthpyroxene make up approximately 95% of the rock.

Southwards the olivine grains become coarser and more euhedral, pyroxene remains dominantly granular but some orthopyroxene grains poikilitically enclose olivine. Post-cumulate plagioclase is more common. The southernmost outcrop of this body consists of plagioclase bearing poikilitic lherzolite. Olivine crystals are subhedral to euhedral and both orthopyroxene and clinopyroxene poikilitically enclose olivine and chrome spinel grains as well as occurring as anhedral intergranular grains.

The second body, exposed along Belmont Road, is similar to the basal part of the Wandle Road body but contains a greater percentage of post-cumulate plagioclase and is slightly coarser-grained. Overall, euhedral to subhedral olivine crystals are poikilitically enclosed by anhedral pyroxene crystals. Chemical analyses of rocks from the ultramafic bodies are shown in table 1 (analyses 9-12).

Ultramafic bodies from western Tasmania are usually layered and the constituent minerals show plastic to solid state deformation characteristics. Neither of these features is found in the ultramafic rocks of the Wandle Road-Belmont Road area. All other Tasmanian ultramafic bodies have undergone a high degree of serpentinization and usually consist of disseminated blocks within a sheared serpentinite sheath. No such features are found associated with the Wandle Road-Belmont Road bodies.

The nearest body of ultramafic rocks to the Wandle Road-Belmont Road area is the Heazlewood River Complex (Rubenach 1973). Plagioclase-bearing harzburgite and lherzolite from this complex are usually interlayered with other ultramafic rock types. They consist dominantly of rounded to elongate anhedral olivine grains poikilitically enclosed by large subhedral grains of orthopyroxene. Plagioclase is either subhedral with an intergranular texture or post-cumulate and interstitial to the olivine and pyroxene crystals. Olivine grains are partly to completely replaced by serpentine-group minerals and plagioclase is replaced by saussurite or hydrogrossular (Rubenach 1973).

SUMMARY

The sequence of mudstone, greywacke, chert and pillowed basalt exposed from along the Arthut River Valley for 14 km north just north of Mt Bischoff is intruded by both ultramafic and mafic rocks. It is probable that the ultramafic rock intruded as magma, which caused thermal metamorphism of the surrounding sedimentary rocks. Boundary faults present appear to be Devonian in age, but the absence of internal deformation structures and

extensive serpentinization suggests that they have not moved significantly from their intrusive position.

Dolerite intrudes the sedimentary/volcanic sequence probably as dykes and differs significantly from the pillowed basalts in that it has lower Zr, Y and TiO_2 contents and different textural features. The intrusive rocks are also more altered.

ACKNOWLEDGEMENTS

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(ms. received 17.12.1981)

PRE-DEVONIAN STRATIGRAPHY AND STRUCTURE OF THE PRION BEACH-ROCKY BOAT INLET-OSMIRIDIUM BEACH COASTAL SECTION, SOUTHERN TASMANIA

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(with eight text-figures and three plates)

ABSTRACT

BERRY, R.F. & HARLEY, S., 1983 (31 viii): Pre-Devonian stratigraphy and structure of the Prion Neach-Rocky Boat Inlet-Osmiridium Beach coastal section, southern Tasmania. *Pap. Proc. R. Soc. Tasm.*, 117: 59-75, three plates. ISSN 0080-4703. Department of Geology, University of Tasmania, Hobart, Australia.

The pre-Devonian stratigraphy of the Prion Beach to Surprise Bay area is composed of four stratigraphic units. The oldest is a (?) Precambrian, slightly metamorphosed, massive dolomite. This is in part the source area for three overlying units of the Denison Group (Late Cambrian to Early Ordovician). The Tyler Creek Beds are highly serpentinitic conglomerate, sandstone and siltstone. The Point Vivian Formation is a sequence of dolomitic siltstone and matrix rich polymictic conglomerates with a wide range of depositional features including channels, graded bedding and slump structures. It was probably deposited in a slope environment. The overlying Wierah Formation (Denison Group) is composed of quartz-rich pebbly sandstones and quartz arenites which formed in a high energy environment possibly above wave base. Two shear zones cut across this stratigraphy producing transposed layers and boudins. At least one of these shear zones was active during sedimentation and forms the western limit of the Point Vivian Formation in this area.

INTRODUCTION

The geology of the Rocky Boat Inlet (fig. 1) area has been studied briefly in reconnaissance surveys of southern Tasmania (Twelvetrees 1915; Banks 1959; Kennedy 1980). It is the southernmost exposure of Early Palaeozoic clastic sediment in Tasmania. Work on Gordon Subgroup sediments to the north and east (Burrett *et al.* 1981 and in press) suggests that the Ordovician sedimentary environment of this region was different from all other known localities. This study of the Early Palaeozoic clastic sediments was designed to determine if the different environment was of prolonged duration or a feature of the Ordovician. In addition the previous studies have shown that the structure of the area is complex, but the very good exposures along the coastal section were probably sufficient to determine the relationship between the lithological units. We have investigated these two aspects of the geology of the area.

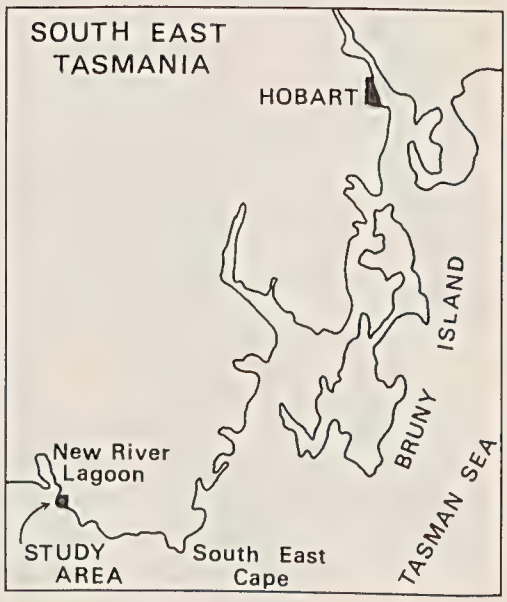

FIG. 1 - Location of Rocky Boat Inlet area, southern Tasmania.

Previous workers in the area interpreted the clastic sediments on Point Cecil as terrestrial conglomerates of the Denison Group and those on Point Vivian as Middle or Upper Cambrian turbidites. In addition a probable Precambrian dolomite was recorded from the western shore of Rocky Boat Inlet.

This information was derived from a number of unpublished sources by Farmer (1979). It was confirmed in a general way by Kennedy (1980), who did not, however, find the Precambrian dolomite. As shown by our mapping this discrepancy was probably caused by the low accuracy of the 1:250 000 map which shows the dolomite closer to the head of Rocky Boat Inlet than its actual exposure.

The field work reported here was carried out in two sections. A preliminary investigation was made as part of a helicopter survey arranged by Dr C. Burrett. After this an expedition was carried out using foot access from Cockle Creek. Section thicknesses have not been measured directly but have been estimated and no exact stratigraphic logging of a specific section was carried out. The 90% exposure along the wave cut platform means that the mapping is reliable in these areas but very little data were available away from the coast and the map reliability drops off rapidly.

STRATIGRAPHY

The rocks of this area occur in four distinct stratigraphic units. Of these two are formal stratigraphic divisions. A massive grey, strongly recrystallized dolomite occurs on the western shore of Rocky Boat Inlet (fig. 2). Its age is problematical. It is unconformably overlain by the Wierah Formation on a probable karst topography. Pebbles of grey dolomite identical to this mass are widely distributed through the lower part of the Point Vivian Formation, but the boundary between these two rock types is a shear zone. White marble and grey dolomites similar to the massive grey dolomite unit are found as boulders in the Tyler Creek Beds. The grey dolomite may correlate with dolomites of probable Precambrian age found to the west (Farmer 1979).

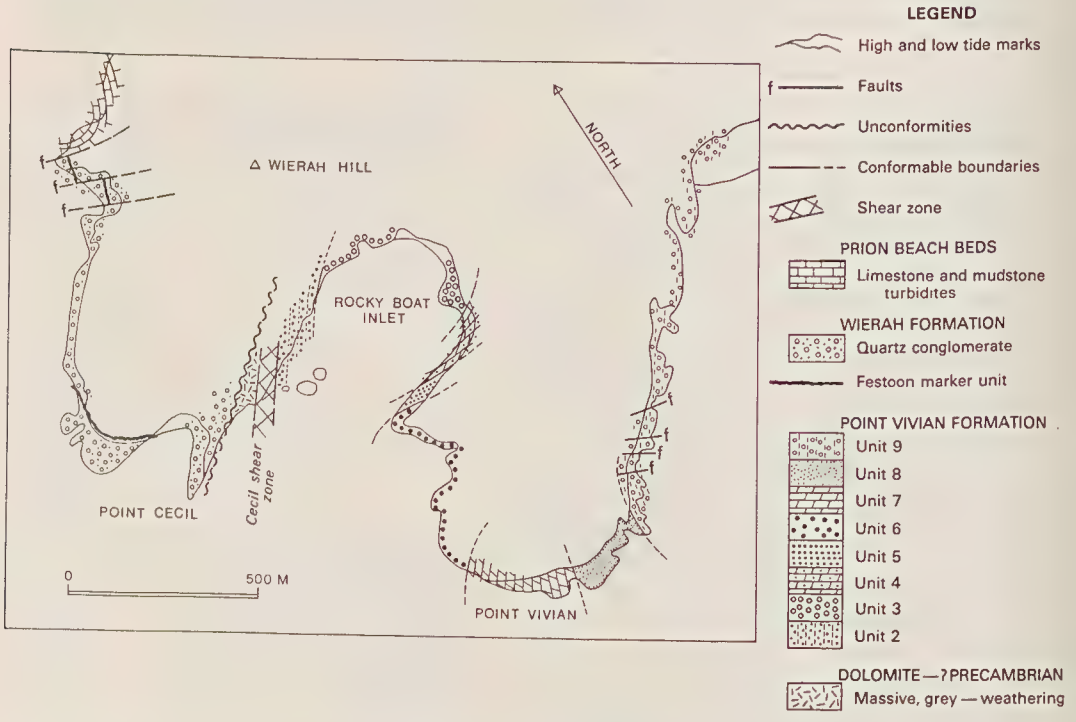

FIG. 2 - Outcrop map of pre-Devonian strata in the Rocky Boat Inlet area.

R.F. Berry and S. Harley

Tyler Creek Beds

The Tyler Creek Beds (new name) crop out for at least one km east of the Osmiridium Shear Zone (fig. 3). This unit is predominantly composed of pale green, calcareous siltstones and arenites which are 0.05 to 0.2 m thick. The arenites have load casts on the base and the siltstones are crossbedded. Less common are pale green, matrix-rich conglomerates which are graded, lenticular and intensely load casted. Clasts vary up to 200 mm and include grey dolomite and serpentinite. The 200 m thick section mapped does not show any systematic variation. It is closely similar to some of the rocks in the Osmiridium Shear Zone but no red-matrix conglomerates or pyritic rocks have been found. The only fossil found in these rocks was a sponge spicule (Banks 1959). The presence of serpentinite clasts supports a Middle or Upper Cambrian age by analogy with other areas of Tasmania (e.g. Rubenach 1974).

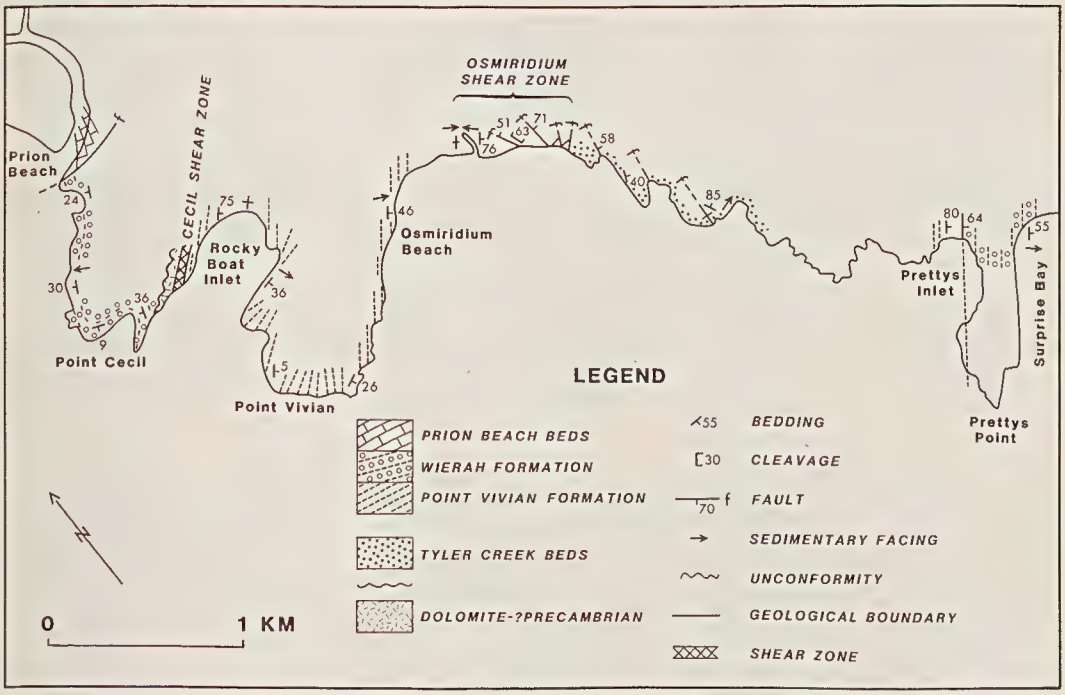

FIG. 3 - Outcrop map of pre-Devonian strata between Prion Beach and Surprise Bay, southern Tasmania.

The Tyler Creek beds are tentatively assumed to underly the Point Vivian Formation. The main evidence for this is the progression of sediment types from the Tyler Creek Beds through the Point Vivian Formation to the Wierah Formation. The conglomerates of the Tyler Creek Beds are polymictic with a very high component of serpentinite and serpentinitic gabbro. Serpentinite clasts are found throughout the Point Vivian Formation but are most common at the base. Quartzite and vein quartz boulders are most common towards the top and are the only clasts in the overlying Wierah Formation. In other parts of Tasmania serpentinitic boulders are an important component only in the Denison Group.

Point Vivian Formation

This outcrops on the coast between the west end of Osmiridium Beach (1:100 000 series Topographic Map 8210 co-ordinates 691784) and western Rocky Boat Inlet (8210 co-ordinates 681767). The formation includes conglomerates, sandstones, siltstones, dolomitic siltstones and dolomite that face and young westwards. Conglomerates and dolomitic rock types pass upwards into siltstones and interbedded siltstone-conglomerate. The Point Vivian Formation is bound to the east by the Osmiridium Shear Zone near Tyler Creek and on the west by the Cecil Shear Zone along western Rocky Boat Inlet. Generalized features of the sequence are presented in fig. 4.

Unit 1. Dolomite, conglomerate and siltstone.

The basal sequence of the Point Vivian Formation is a series of reworked dolomitic sedimentary rocks including grey-dolomite-clast-rich conglomerates often with a brown weathering dolomitic-siltstone matrix, and brown-weathering laminated and cross-laminated dolomitic siltstones. This unit is only exposed in the Cecil Shear Zone and the nature of its relationship to the massive grey dolomite is unclear. No estimate of thickness can be made because of the tight folding and shearing in this zone.

Unit 2. Conglomerate and dark siltstone.

Approximately 40 m of interbedded conglomerates and siltstones overly the dolomitic sedimentary rocks. The conglomerates occur as graded beds and channels up to 3 m thick. They are green and matrix-rich with medium to coarse clasts (2 mm-50 mm) of dolomite, red shale, chert, quartz and serpentinite set in a serpentinitic-chloritic matrix.

Lenses (<1 m) of argillaceous slate, dolomitic siltstone, and cross-laminated siltstone are commonly interlayered with lithic wacke. These siltstones and arenites contain cross bedding, flame structures, ripple marks and slump accentuated ripples.

Polymictic, matrix-supported conglomerates with very-coarse (to 150 mm), well-rounded clasts of dolomite, ferruginous chert, quartzite and quartz phyllite occur in the upper part of this unit.

The presence of medium-grained serpentinite and red shale clasts in the lower part of the unit provides an age constraint for the Point Vivian Formation. The ultramafic source of these clasts was probably emplaced by the late Middle Cambrian, by comparison with other such bodies in Tasmania (e.g. Rubenach 1974). Very coarse serpentinitic breccias and conglomerates occur adjacent to probable layered and altered ultramafics on Surprise Rivulet three km NE of Rocky Boat Inlet. These rocks are most probably the source for the serpentinite clasts observed in the lower part of the Point Vivian Formation. We conclude that the Point Vivian Formation at Rocky Boat Inlet is post-Middle Cambrian.

Unit 3. Coarse conglomerate.

A coarse, clast-supported conglomerate outcrops in the central part of Rocky Boat Inlet. Well-rounded clasts, up to 200 mm in diameter, of quartzite and dolomite occur. Bedding is poorly developed and defined by occasional thin (to 100 mm thick) sandstones lenses.

Unit 4. Laminated siltstone.

A sequence of well laminated, thinly-bedded and ripple-marked dolomitic siltstones and fine sandstones up to 10 m thick overlies Unit 3 on the east side of Rocky Boat Inlet. Asymmetric linear ripples, interference ripples, flames, coherent slump folds, parallel and wavy lamination are well developed in the dolomitic siltstones.

Thin (to 100 mm in thickness), clast-rich conglomerate sheets occur interbedded with the siltstones. These layers have sharp basal and upper contacts suggesting the operation of erosional processes (plate 1A).

Unit 5. Congomeratic sandstone.

Immediately overlying the Unit 4 siltstone is 10 m of poorly-sorted, conglomeratic sandstone. The sandstone is a lithic-quartz arenite containing dispersed, well-rounded

pebbles, and cobbles (20 mm-100 mm in diameter) of quartzite, dolomite and chert.

Unit 6. Polymictic quartz and conglomerate.

Approximately 60 m thickness of polymictic, matrix-poor conglomerate crops out around the east side of Rocky Boat Inlet and forms the high headlands on Point Vivian.

The conglomerate is white weathering with clasts of quartzite, quartz, chert and grey dolomite. Well-rounded clasts up to 150 mm in diameter are supported by finer clasts (5 mm-50 mm). A rough layering into discontinuous and lensoidal beds 1 m to 5 m in thickness is present. Occasional lenses and thin sheets (100 mm thick) of quartz sandstone define this layering.

Unit 7. Dolomitic siltstone.

Thirty metres of well-laminated dolomitic siltstone overlies the Unit 6 conglomerates on Point Vivian. Intense slump folds are developed at the contact. In the lower part of the unit layering forms large scale gentle troughs and undulating megaripples (10-15 m wavelength and 5 m amplitude).

Slumping is developed as coherent S and Z folds, accentuated ripples or cross lamination. Individual siltstone layers sometimes act as decollement surfaces. Disrupted lamellae and sandstone dykes are developed in

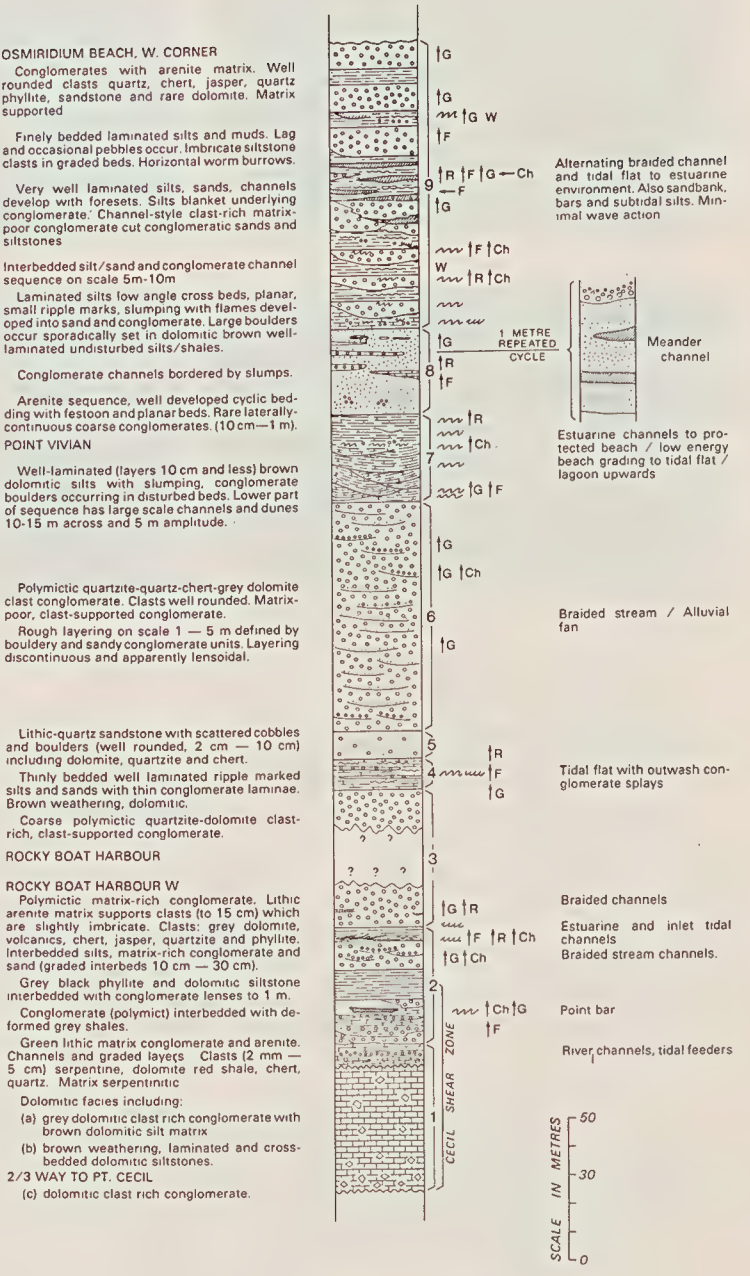
OSMIRIDIUM BEACH, W. CORNER
Conglomerates with arenite matrix. Well rounded clasts quartz, chert, jasper, quartz phyllite, sandstone and rare dolomite. Matrix supported
Finely bedded laminated silts and muds. Lag and occasional pebbles occur. Imbricate siltstone clasts in graded beds. Horizontal worm burrows.
Very well laminated silts, sands, channels develop with foresets. Silts blanket underlying conglomerate. Channel-style clast-rich matrix-poor conglomerate cut conglomeratic sands and siltstones
Interbedded silt/sand and conglomerate channel sequence on scale 5m-10m
Laminated silts low angle cross beds, planar, small ripple marks, slumping with flames developed into sand and conglomerate. Large boulders occur sporadically set in dolomitic brown well-laminated undisturbed silts/shales.
Conglomerate channels bordered by slumps.
Arenite sequence, well developed cyclic bedding with festoon and planar beds. Rare laterally-continuous coarse conglomerates. (10 cm—1 m).
POINT VIVIAN
Well-laminated (layers 10 cm and less) brown dolomitic silts with slumping, conglomerate boulders occurring in disturbed beds. Lower part of sequence has large scale channels and dunes 10-15 m across and 5 m amplitude.
Polymictic quartzite-quartz-chert-grey dolomite clast conglomerate. Clasts well rounded. Matrix-poor, clast-supported conglomerate.
Rough layering on scale 1 — 5 m defined by bouldery and sandy conglomerate units. Layering discontinuous and apparently lensoidal.
Lithic-quartz sandstone with scattered cobbles and boulders (well rounded, 2 cm — 10 cm) including dolomite, quartzite and chert.
Thinly bedded well laminated ripple marked silts and sands with thin conglomerate laminae. Brown weathering, dolomitic.
Coarse polymictic quartzite-dolomite clast-rich, clast-supported conglomerate.
ROCKY BOAT HARBOUR
ROCKY BOAT HARBOUR W
Polymictic matrix-rich conglomerate. Lithic arenite matrix supports clasts (to 15 cm) which are slightly imbricate. Clasts: grey dolomite, volcanics, chert, jasper, quartzite and phyllite. Interbedded silts, matrix-rich conglomerate and sand (graded interbeds 10 cm — 30 cm).
Grey black phyllite and dolomitic siltstone interbedded with conglomerate lenses to 1 m.
Conglomerate (polymict) interbedded with deformed grey shales.
Green lithic matrix conglomerate and arenite. Channels and graded layers Clasts (2 mm — 5 cm) serpentine, dolomite red shale, chert, quartz. Matrix serpentinitic
Dolomitic facies including:
(a) grey dolomitic clast rich conglomerate with brown dolomitic silt matrix
(b) brown weathering, laminated and cross-bedded dolomitic siltstones.
2/3 WAY TO PT. CECIL
(c) dolomitic clast rich conglomerate.
CECIL SHEAR ZONE
1 METRE REPEATED CYCLE
Alternating braided channel and tidal flat to estuarine environment. Also sandbank, bars and subtidal silts. Minimal wave action
Meander channel
Estuarine channels to protected beach / low energy beach grading to tidal flat / lagoon upwards
Braided stream / Alluvial fan
Tidal flat with outwash conglomerate splays
Braided channels
Estuarine and inlet tidal channels
Braided stream channels.
Point bar
River channels, tidal feeders
SCALE IN METRES
50
30
0

FIG. 4 - Stratigraphic log of the Point Vivian Formation. Legend as shown in figure 5.

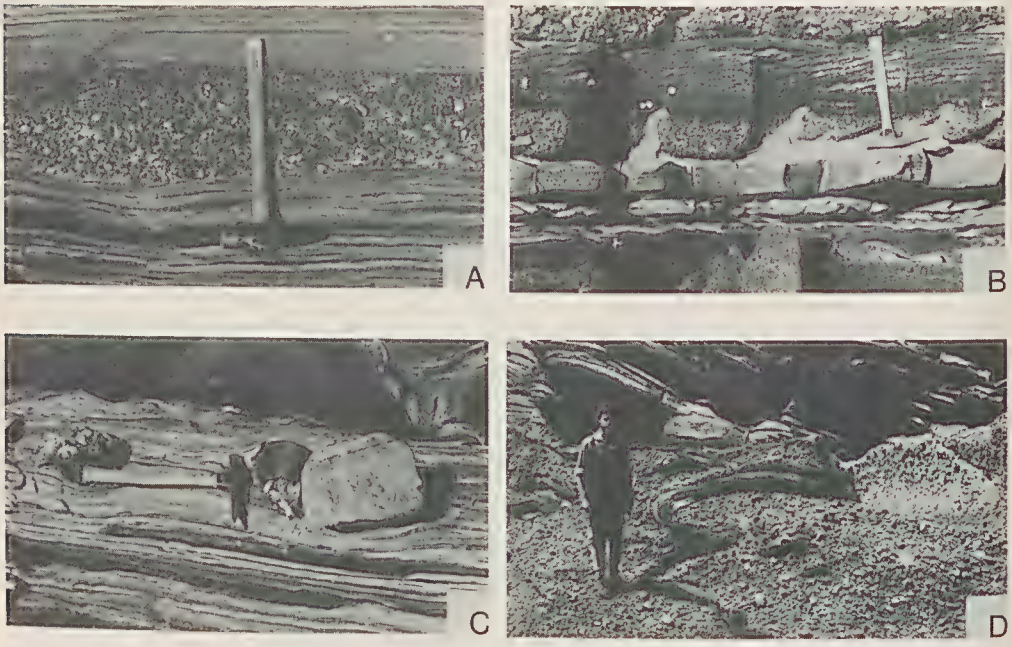

PLATE 1. - A - Thin, graded conglomerate bed in laminated, dolomitic siltstones with sharp upper and lower contacts. Slight channelling accentuated by compaction. B - Asymmetric flame structures extruded from dolomitic siltstone into graded and crossbedded conglomerate-sandstone layer. C - Isolated boulders and boulder clusters within dolomitic siltstones. Boulders partly truncate laminations with additional distortion of layers due to compaction. Note ripple-marked upper surface of dolomitic siltstones. D - Roll folds outlined by dolomitic siltstones within massive channel conglomerate.

some of the larger slump zones. Isolated pebbles, boulders (up to 300 mm diameter) and conglomeratic boulders (500 mm diameter) occur on slump surfaces or in only weakly deformed layers. Marginal deformation and incorporation of dolomitic siltstone indicates that some conglomeratic boulders were only partly consolidated when re-deposited.

Other features developed in the siltstones include small scale cross lamination, graded sandstone, siltstone layers (up to 100 m thickness), and small channels (up to 10 m wide).

Unit 8. Sandstone.

Approximately 30 m of brown-grey sandstone and very minor conglomerate outcrops just east of Point Vivian. This unit is made up of cyclically repeated 1 m thick, slightly-channelled sandstone beds (fig. 4). In each of these beds conglomeratic lag (up to 100 mm thickness) is succeeded by massive to poorly graded, quartz-lithic sandstones. Thin (to 200 mm thickness) cross-bedded sandstone lenses occur, displaying low angle ($<10^{o}$) trough and planar foresets. Ferruginous concretions (<10 mm diameter) are developed in these lenses.

Isolated boulders (to 200 mm diameter) are scattered through the siltstones, and intraformational clasts of dolomitic siltstone occur near the top of individual cycles.

Unit 9. Channel conglomerates and siltstone.

Interbedded channel-filling conglomerates, laminated siltstones, and cross-bedded siltstones and sandstones form the headland along the west end of Osmiridium Beach southwards to near Point Vivian. Five to ten metre thick conglomerate and siltstone-sandstone units are cyclically repeated.

(a) Siltstone. - Thinly bedded grey siltstones and brown weathering dolomitic siltstones occur in units up to 5 m thick. Bedding thicknesses in the laminated siltstones are 10-100 mm, with common erosional, truncated or ripple-soled bedding contacts. Common sedimentary structures include horizontal worm burrows, scour marks under conglomerates, planar lamination, low-angle cross lamination, asymmetric ripples with linear crest lines, and small scale (1-2 m width and 100 mm depth) channels with foresets. Ripple marks imply currents from the north, while foreset orientations indicate channelling from the south.

Flame structures are developed beneath several of the conglomerate beds (plate 1B). Accentuated ripples and tight slump folds are developed in zones up to 100 mm in thickness. Larger scale coherent slump folds and slightly overturned foresets, in sheets up to 300 mm thick, occur in some siltstone layers bounded by sandstones.

Sheet-like, thin (100-300 mm thick) conglomerate horizons showing sharp contacts with enclosing siltstones are present. Isolated large boulders (to 200 mm diameter) and clusters of boulders (plate 1C) are set in undeformed siltstones. Some scour effects with local sand buildups were found adjacent to such boulders.

Siltstones overlying conglomerate channels blanket these with sharp, erosional contacts.

(b) Sandstone. - Impure calcarenites and quartz sandstones form thin sheets and wedge-shaped layers 100 mm - 1 m thick within the siltstones. The sandstones are typified by low-angle planar cross-bedding and superposed shallow wedge-shaped troughs, or by graded bedding. The graded beds show conglomeratic lags, multiple grading, and massive bedding with imbricate siltstone clasts.

(c) Congomerate. - Matrix-poor pebble conglomerates occur as broad channel-like units 3-10 m in thickness and separated by the siltstone units. The polymictic conglomerates are mainly clast-supported, with up to 90% round to sub-rounded clasts including quartz, quartz-phyllite, chert, siltstone and some dolomite.

The conglomerate units have upper surfaces truncated by siltstone. Channel floors and sides are often slump folds. Syn-depositional faults occur in these areas and die out upwards towards disconformable siltstone-siltstone contacts above the conglomerates.

Within individual channels the conglomerates are usually massive, but grading into sandstone horizons occur in rare matrix-supported conglomerates. Some channels have been filled and subsequently scoured then refilled with further conglomerate. In such channels, roll-folds have developed in partly consolidated siltstone layers (<150 mm thickness) which have been extruded into the channels synchronous with conglomerate deposition (plate 1D).

Near the top of unit 9, at an unconformable contact with probable Tertiary and Quaternary sediments in the western corner of Osmiridium Beach, the conglomerates contain more matrix (20-25%) and include occasional poorly-sorted sandstone horizons. Solution zones containing carbonaceous soily deposits penetrate these conglomerates from the unconformity. These carbonaceous deposits are the cause of the previous erroneous assignment of a Tertiary age for these conglomerates (Twelvetrees 1915; Berry & Harley 1982).

The Point Vivian Formation also crops out in Prettys Inlet (fig. 3) where the sequence is conformably overlain by quartz sandstones and siltstones which correlate with the Wierah Formation. This eastern exposure is dominated by matrix-rich conglomerates with boulders and cobbles of quartzite, vein quartz, sandstone, dolomitic breccia and rare serpentinite. The conglomerates have boulders of quartzite up to 1 m in diameter. They

are interbedded with sandstone with common horizontal burrows and, in one case, large numbers of silicified brachiopods. One 2 m thick bed of dolomite crops out 50 m below the contact with the Wierah Formation.

Provenance

Clast types in conglomerates of the Point Vivian Formation are of similar origin to clastic particles in the interbedded siltstones and sandstones. Siltstones are often calcareous, dolomitic, and contain clasts of dolomite, calcite and abundant quartz or quartzitic rock fragments.

In siltstones and calcareous sandstones, undulose and lamellar quartz grains of metamorphic origin are angular to subangular. Heavy mineral grains (ilmenite) occur, and subangular-subrounded rock fragments of polygonal granoblastic quartzite, recycled sparite, and siltstone-mudstone are common. Metamorphic muscovite, usually undulose or kinked, occurs in some siltstones.

A dolomite clast exhibits granoblastic polygonal recrystallised texture, and may have been weakly metamorphosed. This fragment appears to be identical with the massive grey dolomites on the western side of Rocky Boat Inlet.

The source area for most of the Point Vivian Formation is the Precambrian metamorphic basement which is exposed immediately west and northwest of New River. In the lower part of the formation, serpentinitic clasts, discussed above, indicate a Cambrian source area. This source area was possibly a minor high in the region of the Surprise Rivulet ultramafic body.

Depositional Environment

The most striking feature of the Point Vivian Formation, above the basal dolomitic facies, is the interbedding of contrasting conglomeratic and siltstone facies, often with sharp erosional contacts. In the lower part of the sequence conglomerate units are quite thick (to 50 m), while siltstones are less common. Higher in the sequence, towards Osmiridium Beach, conglomerate and siltstone occur in nearly equal abundance and the conglomerates form obvious channels. Any model for a depositional environment must account for these features as well as embracing more detailed sedimentological evidence from individual units.

The association of slumped beds, pebbly mudstone, turbidites, hemipelagite and channel deposits is characteristic of slope deposits (Stanley & Unrug 1972). The Point Vivian Formation contains sedimentary rocks with these characters.

The main evidence against of slope deposit is the widespread dolomitic siltstones. Dolomites are commonly found near basin margins which suggests the Point Vivian Formation may correlate with continental margin fans prograding over intertidal and low subtidal carbonates (e.g. Miall 1970) but this formation lacks all the other features of such shallow water sedimentation (e.g. mudcracks, evaporite casts, red beds, algal mats). The medium-grained, recrystallised texture of dolomite in the Point Vivian Formation suggests diagenetic dolomitisation which is not restricted to shallow water conditions (Zenger 1972). The environment of deposition of the Point Vivian Formation remains in doubt but it may be similar to the submarine fan environment of the Singing Creek Formation, Denison Ranges (Corbett 1970, 1975) which is of comparable age.

Wierah Formation

Unconformably overlying the massive dolomites of western Rocky Boat Inlet is a thick (>100 m) sequence of coarse conglomerates with rare layers of sandstone and chert. This unit outcrops from Point Cecil where it unconformably overlies massive dolomites (8210 co-ordinates 677766), to the entrance of New River Lagoon (8210, 67774), where it is in fault contact with the Prion Beach Beds of Middle and probably Upper Ordovician age (Burrett *et al.* 1981). The Wierah Formation (>100 m in thickness) consists almost wholly of thick plane-bedded conglomerates, with rare sandstone and siltstone layers 5 m thick with interlayered thinner bands of sandstone and conglomeratic sandstone (300 mm - 1 m

thickness) (fig. 5). The conglomerates are characterised by well-rounded quartz phyllite clasts (to 200 mm diameter) and vein quartz pebble clasts (10-50 mm diameter), set in finer quartz clasts. Massive units alternate between phyllite clast-rich and vein quartz clast-rich types, most layers being bimictic.

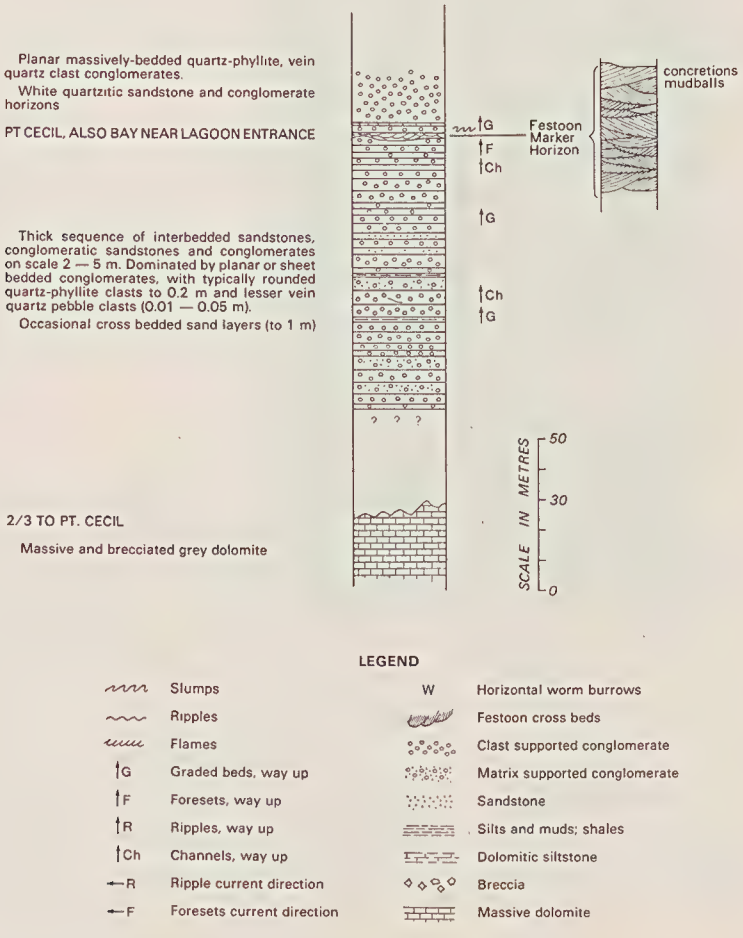

FIG. 5. - Stratigraphic log of the Wierah Formation.

Near the top of the sequence, at the western headland of Point Cecil and in a down-faulted block in a small bay near the entrance to New River Lagoon, are two marker horizons. The uppermost of these is a 500 mm - 1 m thick massive quartzitic sandstone with minor pebbly horizons.

Occurring about 3 m below the quartzitic horizon is a 1-2 m sandstone horizon (Festoon sandstone marker horizon, fig. 2) weathering brownish grey. This is a quartz sandstone with silica cement. The sandstone is characterised by low-angle trough cross-beds 100-200 mm thick, multiply scoured to form cosets. Fine, spherical, ferruginous concretionary mudballs 2-20 mm in diameter occur in the foreset beds and do not disturb the layering. Minor siltstones overlying this horizon contain horizontal worm burrows and ferruginous layers.

Four kilometres to the east at Prettys Point, cross-bedded and worm-burrowed quartz sandstones interbedded with quartz siltstones conformably overlie the Point Vivian Formation. We correlate these beds with the Wierah Formation on the basis of their stratigraphic position, and the absence of polymictic conglomerates and carbonates.

Provenance

The dominant clast type in the conglomerates and associated sands is quartz-phyllite, with vein quartz also common. The quartz-phyllite is typical of quartzitic metamorphics outcropping to the west and northwest in the Tasmanian Precambrian basement, which occurs as close as New River. Vein quartz may also be derived from this metamorphic source region. Comparative paucity of other clast types suggests that these conglomerates were derived from a close metamorphic source region with little input from more diverse areas.

Depositional Environment

The sheet-like layering of the conglomerates contrasts with the channel structures of the Point Vivian Formation. The massive pebbly sandstones implies deposition in the high flow regime or as debris flows. The low abundance of clay in the sands suggests the former environment although it may be the result of the very quartz-rich provenance of these rocks. The festoon crossbedded sandstones horizon implies moderate rates of deposition in the lower flow regime (Allen 1973). The presence of horizontal worm burrows is the principal evidence of a marine origin for these sediments. The high energy of deposition and good sorting suggests they may be deposited above wave base. The sediments of Prettys Point are apparently of lower energy and may have been deposited in deeper water.

STRUCTURE

Grey-weathering Metamorphosed Dolomite

The massive dolomite on the western shore of Rocky Boat Inlet (fig. 2) has not yielded any structural data. The outcrop is bounded on the east by an apparently conformable sequence of Point Vivian Formation. However this contact is a shear zone (referred to here as the Cecil Shear Zone) with intense transposition, tight folding (plate 2) and brecciation. The presence of clasts of dolomite identical to this unit throughout the lower half of the Point Vivian Formation does suggest a substantial erosional unconformity has been concealed by this shear zone. In addition the juxtaposition of presumably older Point Vivian Formation with the Wierah Formation suggests a reverse component of motion on this steeply dipping shear zone.

Denison Group

The vast majority of deformed Palaeozoic rocks in this area have simple deformation history. The poles to bedding (fig. 6) form a broad great circle which indicates fold axes plunging shallowly to 200°. The folds of this orientation are asymmetrical with small areas of shallow westerly dips as on the western side of Point Cecil and structural terraces as on the western side of Point Vivian.

A very weak cleavage is locally developed parallel to this fold axis orientation and is probably parallel to the axial plane of these folds. However, no small scale folds of this generation were observed outside the shear zones. The cleavage is a spaced cleavage in limestones where it is best developed. It dips steeply both west and east, and strikes at 020°.

The Tyler Creek Beds do not fit this distribution and appear to be rotated by faults similar to those in the Osmiridium Shear Zone. A second set of folds has distorted the bedding orientations produced by the early folding. These have only been recognised on Point Vivian and are with one exception limited to the structural terrace mentioned earlier. They are tightest on the southern end of Point Vivian where they form asymmetric upright open folds with steep north-dipping limbs and shallow south-dipping limbs. The axial surfaces of these folds strike 105° and dip steeply south. A domain analysis of the structural terrace assuming deviations from a simple great circle distribution were due to this

PLATE 2. - Tight fold in Unit 2 conglomerates of Cecil Shear Zone. Note bent and flattened quartzite pebbles in hinge zone.

phase of folding produced the interpretation of macroscopic D_2 fold closures shown in Fig. 7. The tightness of these closures varies from gentle for the northern anticline to open for the southern anticline. The boundaries of the structural terrace are shown as F_1 macroscopic folds.

There is a small deviation from a simple great circle distribution in the Wierah Formation and this indicates a steepening of the early phase fold axes at the southeastern end of Point Cecil. It is not clear if this is the result of F_2 folds or of proximity to the Cecil Shear Zone.

The Prion Beach Beds are complexly folded, possibly partly as a result of D_2 folds. A small area of intense folding of a similar orientation occurs at Surprise Bay and is closely related to strike-slip faults dipping 70° towards 340°. We interpret these as D_2 folds.

Minor faulting is very common in the Point Vivian Formation. One set of faults strikes 120° and dips shallowly both south and north. Slickensides on one of these faults indicates dip-slip motion and offset of recognisable beds implies the motion is in a reverse sense. These two fault orientation are probably a conjugate set and are compatible with σ_1 horizontal and trending 025°. These faults all occur in the steep east-dipping limbs of the D_1 folds and their orientation suggests that they were formed under the same stress/strain conditions as the D_2 folds. The absence of D_2 folds in these beds contrasts with the open buckles of the flat-lying beds nearby. This distinct zonation of D_2 struc-

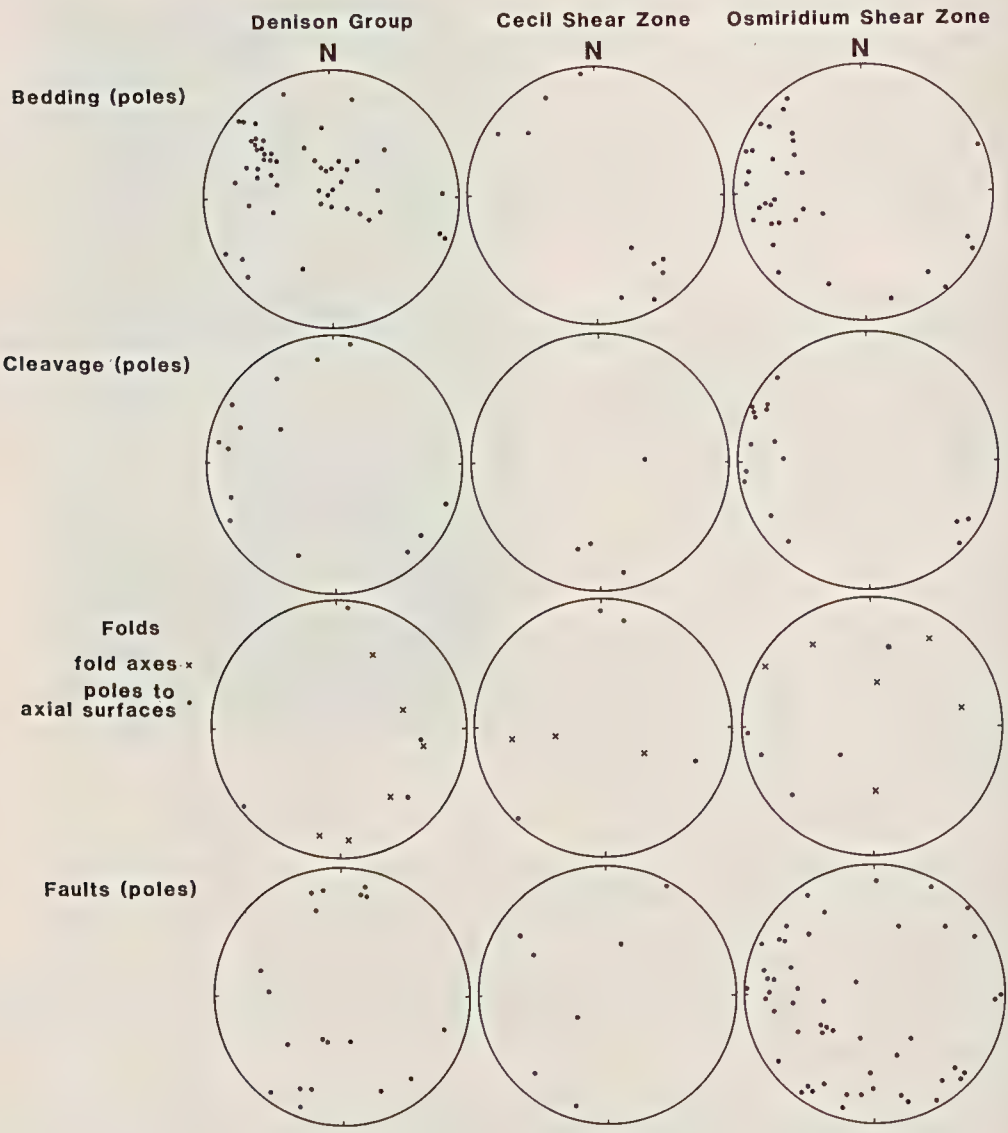

FIG. 6. - Lower-hemisphere equal-area stereographic projections of structural data from the Denison Group.

tures with folds forming on the D_1 structural terrace and thrust faults on the moderate to steeply dipping limbs, is the major evidence we have found for the relative ages of D_1 and D_2. The correlation of D_2 with the fault-related folds at Surprise Bay supports this interpretation since these folds post-date the S_1 cleavage.

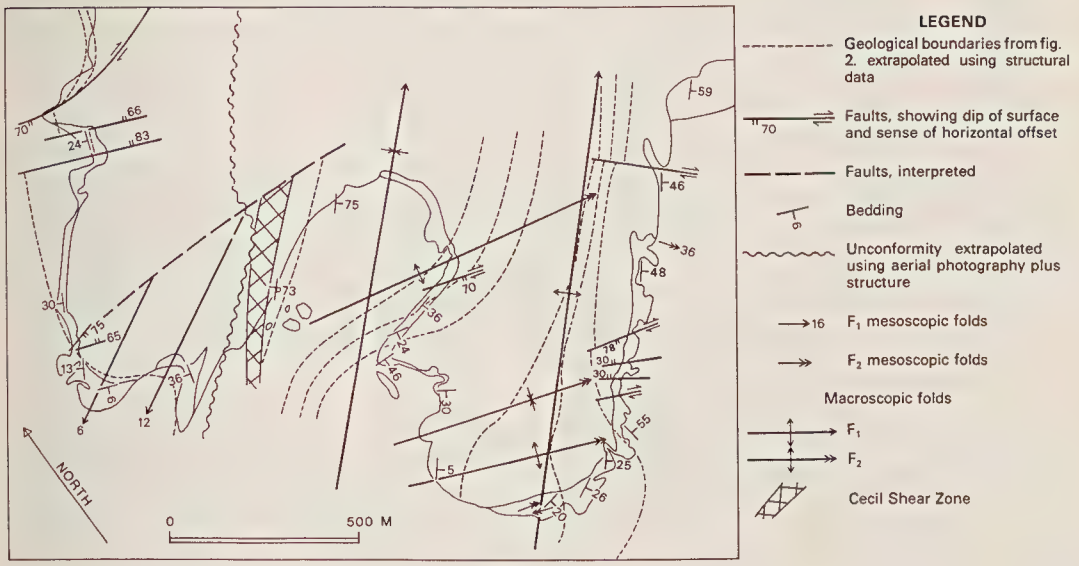

FIG. 7. - Interpretative structural map of the Rocky Boat Inlet area. Macroscopic folds shown are domain boundaries defined on bedding orientation as discussed in the text.

A second orientation of faults was recognised on the eastern side of Point Vivian. A series of small right-lateral offsets occurs on near-vertical faults which strike 105° and a conjugate set of left-lateral faults occurs with smaller displacement and a strike from 135 to 165°. These faults were formed in a stress environment where σ_1 was near-horizontal and had a trend of 130°. We have considered a possible correlation of these faults with the D_1 folds. However a similar fault which cuts Prettys Point a few kilometres to the east also probably offsets Permian sediments on Shoemaker Point so at least some of the motion of these faults is post-Permian..

The Wierah Formation is cut by a large number of conjugate normal faults. The orientation of these faults indicates σ_3 horizontal and trending 015° and σ_1 trending 280° and plunging moderately. These faults usually have a small net slip. The largest motions were found on two faults in the small bay near the outlet of the New River. They have an offset normal to bedding of 50 m. Finally, just to the north, the Prion Beach Beds are faulted against the Wierah Formation along a fault of nearly the same orientation. This fault appears to be a right-lateral, strike-slip and its orientation is similar to that of right-lateral faults in the Point Vivian Formation. South dipping faults in the Wierah Formation have a strike of 085° and the stress interpretation predicts a significant right-lateral component. It is likely that all these faults are the same age.

Shear Zones

The pre-Devonian sedimentary rocks of the study area are cut by two intensely sheared zones referred to here as the Cecil Shear Zone and the Osmiridium Shear Zone (fig. 3). In both cases these consist of a gradation from close coherent folds in recognisable sedimentary rocks through transposed sediments and finally to breccias. The cleavage developed in open and tight folds is very weak and only recognisable in suitably etched rocks. Clasts in the conglomerates are bent around some of these folds. In the Osmiridium Shear Zone compositional layers are often defined by a series of rotated blocks bounded on one

side by curved faults and on the other by bedding (phacoids). The origin of the breccias is ambiguous since many of the sedimentary rocks which are included in these zones are polymictic conglomerates and there is a complete transition from coherently deformed sedimentary rocks to "tectonic" breccias. Local stratigraphic coherence can be recognised in the Cecil Shear Zone and in part of the Osmiridium Shear Zone but the high intensity of shearing is evident from the incorporation of an exotic block of pyritic limestone 30 m across in the clastic matrix of the latter. In combination all these features fit the definition of melange proposed by the 1979 Penrose Conference (Silver & Buetner 1980).

The boundaries of these shear zones are gradational. The Cecil Shear Zone appears to be entirely composed of Point Vivian Formation rocks and on the eastern side grades from tightly folded and sheared rocks through steeply dipping beds to the flat lying sedimentary rocks at the head of Rocky Boat Inlet. On the western side this shear zone has a sharp contact against the massive dolomites. There are clasts of this dolomite in the shear zone but these are at least partly cobbles and boulders from the basal part of the Point Vivian Formation. The shear zone is cut by many faults of variable orientation and often containing slickensided calcite veins. These faults are commonly sub-parallel to the limbs of tight folds.

The Osmiridium Shear Zone is predominantly composed of laminated siltstones, lenticular sandstones and matrix-rich conglomerates. Clasts in the conglomerates include serpentinised gabbro, chert, red limestone, white marble, dolomite, vein quartz, greywacke, quartzite, basalt and serpentinite. The matrix is either a red mudstone or a pale-green calcareous arkose. Clasts are up to 0.5 m in diameter. Major exotic blocks at the eastern edge of this zone include a layered and bioturbated pyritic limestone, pyritic dolomite shale, bedded pyritic shales and siltstones. The eastern margin is defined here as a fault against Tyler Creek Beds at the eastern end of Osmiridium Beach (fig. 3). The Tyler Creek Beds are closely similar in composition to the conglomerates and siltstones which make up the majority of the Osmiridium Shear Zone.

The bedding of the Osmiridium Shear Zone is steeply dipping to the east with variable strike but predominantly 350° to 040° (fig. 6). Locally a cleavage parallels the bedding, but it is not clear if this represents a sedimentary or a tectonic structure. The outstanding feature of this area is the intense faulting which occurs on all scales. An attempt to show a representative sample of these faults is made in fig. 6. There is a very wide range in orientations of faults in this zone and the only clear trend is a general dip towards the north and east. A significant proportion of the faults are parallel to the layering. A high proportion of faults in this unit contain fibrous calcite veins which indicate a wide range of slip vectors and in some cases two separate slip orientations on the same fault. No pattern has been recognised in the movement directions of these faults.

Other evidence is available for the history of strain in these rocks. Calcite-filled extension fractures are common throughout the conglomeratic units. The distribution of these fractures (fig. 8) strongly suggests a flattening plane which dips 70° towards 215°. Striated edges of dolomitic clasts in these conglomerates (plate 3) show two sets of striations, a near-horizontal set and a near-vertical set, supporting a two stage strain path for the Osmiridium Shear Zone.

The Cecil Shear Zone forms the western boundary of the Point Vivian Formation. To the east a thick sequence of sediments underlies the Wierah Formation but to the west the Wierah Formation sits unconformably on the ?Precambrian dolomite. The Cecil Shear Zone must have been an active fault during the Cambrian sedimentation. Such synsedimentary faults are well established in the Cambrian of Tasmania (e.g. Corbett 1970).

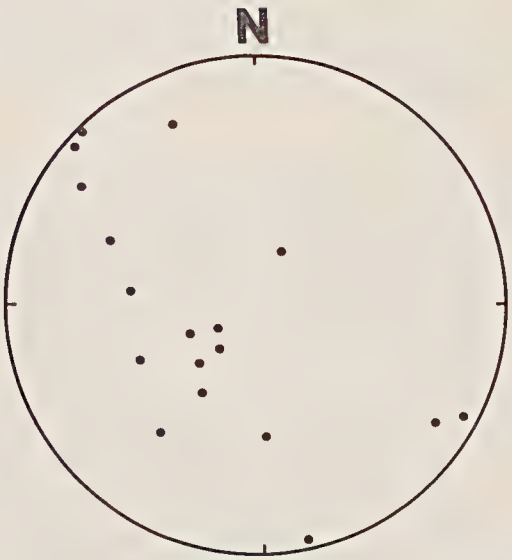

FIG. 8. - Lower-hemisphere equal-area stereographic projection of poles to extension fractures in the Osmiridium Shear Zone.

PLATE 3. - Dolomite cobble in Osmiridium Shear Zone showing two sets of tectonic striations (parallel and perpendicular to the pencil).

Summary and Correlations

Early Palaeozoic sediments of the Rocky Boat Inlet area have a simple structural history. Early open to gentle folds occur in all the sequences. A second generation of open folds strikes 105° and is correlated with minor faulting. Finally a set of strike slip faults in the Point Vivian Formation and normal faults in the Wierah Formation both imply σ_3 was near-horizontal and trending 020°. These fault sets both appear to be post-folding and in the former case is likely to be post-Permian.

On the western side of Rocky Boat Inlet and on Osmiridium Beach deformation is much stronger, forming distinct shear zones with a steeply dipping foliation. The Cecil Shear Zone contains tight folds of similar orientation to the early folds in the less deformed sequences. It has a relatively coherent appearance suggesting relatively small strains. The Osmiridium Shear Zone is dominated by brittle behaviour, contains blocks of exotic material and has had both dip-slip and strike-slip motions.

The correlation of fold structures affecting Lower Palaeozoic rocks over large distances in Tasmania has seldom been successful. The structures have orientations strongly controlled by the local basement orientation and especially in the northwest of the State this has produced a large number of fold orientations (Seymour 1980). However, in the southern areas there are some generally consistent observations despite substantial differences in detail.

Solomon (1962) recognised two generations of folds in the Queenstown area. He suggested the N-S trending phase was early and that WNW-ESE trending folds crosscut this sequence. Baillie & Williams (1975) confirmed the relative ages of these two deformations. Both deformations produced an axial plane cleavage but the early N-S cleavage was more extensively developed and the WNW striking cleavage was best developed near Queenstown. Cox (1981) correlated minor thrust faults in the Queenstown area with D_2 folds and suggested post-D_2 strike slip faults. Sharples (1979) identified doubly plunging N-S trending, open upright folds at Ida Bay.

The structure of the Rocky Boat Inlet is very similar to the folds in these areas. The early folds are dominant and strike NE. The second set is less important, closely associated with faulting, and strike ESE. This correlation supports the relatively poor dating evidence available in the region for the relative ages of the folds.

The Cecil Shear Zone and the Osmiridium Shear Zone are similar to well known structures further north. The Cecil Shear Zone is similar in appearance to the tightly-folded siliceous clastics underneath the Pioneer Beds east of the Lyell Mine where folds have been interpreted as slump folds (Solomon 1964, p.282). At Point Cecil the beds were folded while under substantial confining pressure since quartzite pebbles have been bent around the folds (plate 2). However there is little cleavage development even where interlimb angles are less than 20°. The Osmiridium Shear Zone is similar to the intensely deformed Cambrian sequence east of Penguin and at Adamsfield. However, not enough is known at this stage to support this correlation.

SUMMARY

Four major stratigraphic divisions have been proposed for the coastal exposure near Rocky Boat Inlet. A massive grey dolomite of probably Precambrian age has a very limited exposure on the western shore of Rocky Boat Inlet. The Tyler Creek Beds are pale green, graded sandstone and siltstone exposed on the coastal section east of Osmiridium Beach and form the predominant rock type in the Osmiridium Shear Zone. The Point Vivian Formation contains interbedded dolomitic siltstones, sandstones and polymictic conglomerates probably deposited on a steep slope. Deposition was post-Early Cambrian and pre-Devonian, with a probable age of Middle to Upper Cambrian. The Wierah Formation unconformably overlies the massive grey dolomite. This formation is composed of plane-bedded dimictic conglomerates with rare sandstones and siltstones. The age is poorly constrained, but this formation is certainly pre-Devonian and probably Upper Cambrian or Lower Ordovician based on lithological correlations with the Denison Ranges.

Two generations of folding, correlated with the Tabberabberan Orogeny of Devonian age, have been found in the area. The earliest phase produced upright folds with an axial surface striking NE. A second phase of folding was recognised on the southern end of Point Vivian. It has a steep axial surface striking 100° and is associated with minor thrusting. Late strike-slip faults post-date both fold phases.

There are two shear zones developed in the Denison Group. Both contain a range of structures from tightly folded coherent sedimentary rocks to incoherently sheared rocks. These zones are faulted on all scales and have a complex deformation history. The Cecil Shear Zone was active during Cambrian sedimentation. The Osmiridium Shear Zone has had at least two distinct episodes of faulting.

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TREE SPECIES REGENERATION AFTER LOGGING IN TEMPERATE RAINFOREST, TASMANIA

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(with three tables and one text-figure)

ABSTRACT

CALAIS, S.S. & KIRKPATRICK, J.B., 1983 (31 viii): Tree species regeneration after logging in temperate rainforest, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 117: 77-83. ISSN 0080-4703. Department of Geography, University of Tasmania, Hobart, Australia.

Selective mechanized logging for *Athrotaxis selaginoides* in temperate rainforest south of Rosebery in western Tasmania has resulted in a maze of logging tracks and associated destruction of part of the forest by firing. Mapping and analysis of regeneration of *A. selaginoides*, *Phyllocladus asplenifolius*, *Eucryphia lucida* and *Nothofagus cunninghamii* at sites logged ten and twenty years previous to the study suggest that little successful tree establishment can be expected on areas where the topsoil has been removed by bulldozers, although the sides of the tracks where this material has been piled promise a restoration of the forest canopy. *A. selaginoides* and *P. asplenifolius* establish in low densities after logging but appear to have low apparent rates of mortality in contrast to *E. lucida* and *N. cunninghamii* which establish in high densities, but have high apparent rates of mortality.

INTRODUCTION

Temperate rainforest, consisting of tall closed-forest, tall open-forest, closed-forest, open-forest and closed-scrub (Specht 1974) dominated by mostly microphyllous species in the genera *Nothofagus*, *Atherosperma*, *Phyllocladus*, *Athrotaxis*, *Eucryphia*, *Lagarostrobos* and *Anodopetalum* covers a substantial proportion of the area of Tasmania where precipitation exceeds 1250 mm per annum (Jackson 1968). These forests have been cut for timber at least since 1819, being most thoroughly exploited where *Lagarostrobos franklinii* or *Athrotaxis selaginoides* were common (Kirkpatrick 1977a). Although Howard (1973, 1974) has investigated the natural regeneration of *Nothofagus cunninghamii*, nothing is published on the responses of the temperate rainforest tree species of Tasmania to selective logging and associated disturbances. This study compares the regeneration found in undisturbed *Athrotaxis selaginoides-Nothofagus cunninghamii* closed-forests with that found ten and twenty years after logging and identifies the post-logging environments in which the various tree species most successfully regenerate.

THE STUDY AREA

The rainforests studied lie between Rosebery and Queenstown in western Tasmania (fig. 1). The climate is cool perhumid with no months receiving less than 120 mm precipitation and low winter mean monthly temperatures. The rainforests occur on argillaceous, yellow podzolic soils formed on the Mt Read Volcanics. These soils are acid in reaction throughout the profile and incorporate 20-40 percent organic matter in the surface horizon. The rainforest changes from a species-poor, structurally simple closed-forest at low altitudes on good sites to a species-rich and structurally complex closed-scrub on poor and/or high altitude sites (Kirkpatrick 1977b). There is continuous floristic and structural variation between these extremes.

Parts of the rainforests were logged for *Athrotaxis selaginoides* in the late nineteenth and early twentieth centuries using horse and bullock teams and tramways. More recent logging of *A. selaginoides* has employed bulldozers and trucks. The bulldozers have created a dendritic maze of snig tracks and logging roads and many fires have originated from these access lines. At least four major fires have destroyed rainforest in the study area (1896, 1928, 1963 and 1974/5) and smaller fires, many lit by bulldozer drivers and

loggers, have been much more frequent. The logging of *A. selaginoides* in the area ceased in 1978, the resource having been exhausted.

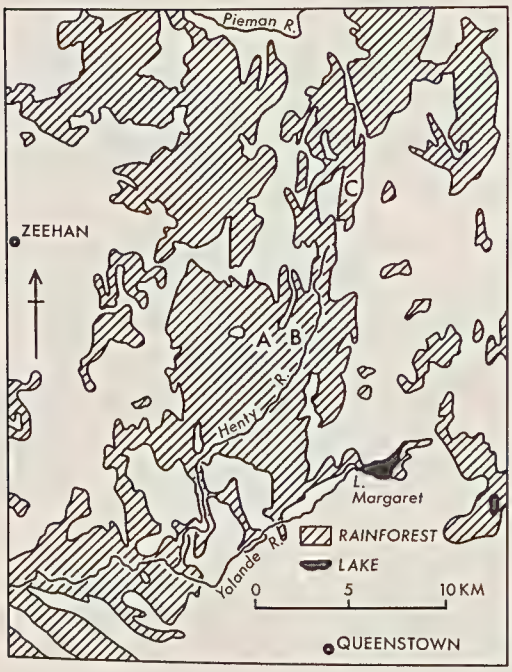

FIG. 1 - The extent of rainforest in the study region, locations mentioned in the text, and locations of groups of transects.

METHODS

Areas logged 10 years previously (A, fig. 1), 20 years previously (B, fig. 1) and never logged (C, fig. 1) were located in 1976 in rainforest with the same species composition in the undisturbed parts of the vegetation. Thirty-three transects consisting of 10 one m^2 quadrats oriented orthogonally to snig tracks were laid out in the logged forests. Seven transects consisting of 10 two m^2 quadrats were laid out in the undisturbed forest. For each of the quadrats the location of all individuals of shrub and tree species was mapped and height-coded in the following classes: 0-0.1 m, 0.1-0.2 m, 0.2-0.4 m, 0.4-0.8 m, 0.8-1.6 m, 1.6+ m. Ring counts were made to correlate size classes with age by species. The extent of mosses and lichen, ferns, logs and stumps, bare ground and *Gahnia grandis* was also mapped for each quadrat. Note was made of whether the quadrat fell within the 'scraped' environment of the centre of the bulldozed logging tracks where soil had been removed, the 'pilings' environment of the side of the snig tracks where soil and dead wood has been pushed, or undisturbed soil. Aspect and slope were recorded and a sample of the top 70 mm of soil removed for later analysis for organic matter content using the rapid titration method of Walkley & Black as described in Piper (1956).

The density of all tree and shrub species in each height class for each quadrat was counted from the maps, and the cover of the various ground cover types was placed into the following classes for each quadrat: 1-10%, 11-25%, 26-50%, 51-75%, 76-100%. The mean density for each species and each size class of each species was calculated for each environment and ground cover type for all quadrats, 10-year logged quadrats and 20-year logged quadrats. For these analyses a ground cover type was assumed to be present in a quadrat if it covered 26% or more of its area. The mean percentage cover of the five ground cover types was calculated for each logging and environment type. The differences observed are real in as much as the selected transect sites belong to the same vegetation type. Thus, these differences are not appropriate for statistical testing.

RESULTS

Regeneration of Ground Cover

The 10-year, 20-year and undisturbed sites differ markedly in the percentage cover of each of moss, ferns, *Gahnia grandis*, logs and bare ground (table 1). Moss cover, slightly greater on the scraped than the pilings environment, approximately doubles on the logged areas from 10 to 20 years, but forms dramatically less of the ground cover in the undisturbed forest. Fern cover increases through time on the scraped environment, but decreases on the pilings environment. In the undisturbed forest ferns, mainly *Blechnum wattsii*, account for 10% of the ground cover. *Gahnia grandis* tussocks account for almost 10% of the

TABLE 1

PERCENTAGE COVER OF GROUND COVER TYPES IN LOGGED AND UNDISTURBED FOREST

Forest Environment	Moss	Ferns	Logs	*Gahnia*	Bare Ground
Scraped:					
10 years	32.6	2.9	1.6	8.5	54.4
20 years	60.8	4.1	2.8	18.1	13.2
Pilings:					
10 years	23.7	10.5	21.0	13.4	31.4
20 years	54.4	6.3	14.7	16.7	7.9
Undisturbed	11.0	10.4	8.1	0.9	49.9

cover in the 10-year scraped environment, slightly more on the 10-year pilings and at 20 years more than doubles on the scraped areas and increases slightly on the pilings. *Gahnia* has negligible cover in the undisturbed forest. Bare or litter covered ground is greater on the scraped areas than on the pilings and decreases dramatically from the 10-year to 20-year sites. In the undisturbed forest litter covers almost half of the ground. Log cover is extremely low in the scraped areas and much higher on the pilings than in the undisturbed forest.

The scraped environment is subject to the accumulation of water in hollows on the gentler slopes and accelerated gully and sheet erosion on the steeper slopes. The organic content of the soil is minimal, determinations ranging from 0.001% to 5.09% in the top 70 mm with a mean of 2.85% (n = 6). The pilings environment is far more heterogeneous with logs, topsoil from the scraped areas and logging debris creating a variety of microhabitats. Drainage is usually free. The determinations of organic matter content of the pilings topsoil varied from 1.3% to 40.4% with a mean of 16.2% (n = 24). In the undisturbed forest the organic matter contents measured varied between 20.2 and 40.8% with a mean of 33.1% (n = 4).

Regeneration of Forest Trees

Nothofagus cunninghamii, *Eucryphia lucida*, *Phyllocladus asplenifolius* and *Athrotaxis selaginoides* were the only tree species in the study area sufficiently frequent to include in the analyses. In the undisturbed forest *A. selaginoides*, *N. cunninghamii* and *E. lucida* are approximately equally abundant in the tree and sapling layers and *P. asplenifolius* is frequent but considerably less common. Recruitment is continuous for all four species in the undisturbed forest (table 2).

Nothofagus exhibits dense regeneration on both the scraped and piling environments ten years after logging. Twenty years after logging the density on the scraped environment decreases from 6.4 individuals per m^2 to 0.5 and on the pilings environment from 7.5 to 2.0. In both cases there is no major shift in the size class distribution (table 2), which suggests that mortality is high and recruitment continuous. *Nothofagus* regenerates most densely in moss and on bare ground in the logged areas, but it is only where moss cover is present that the proportion of tall seedlings is higher in the 20-year than in the 10-year quadrats (table 3).

Eucryphia regeneration is less dense than that of *Nothofagus* on both the 10-year scraped and piling environments, but more dense on both environments on the 20-year site (table 2). Although there is a marked increase in seedling density through time on the scraped environment the seedlings were generally smaller on the 20-year site (table 2) suggesting an extremely high rate of both recruitment and mortality. In contrast, there is a decrease in density but an increase in height on the pilings environment (table 2). *Eucryphia* maintains relatively high densities through time on quadrats with all types of ground cover, but it is only on quadrats with substantial areas of ferns, bare ground or

TABLE 2

SPECIES REGENERATION:
Height class distribution and mean density by environment.

Forest Environment	Tree Species*	Height Classes (m) 0-0.1	0.1-0.2	0.2-0.4	0.4-1.6	>1.6	Mean density (m^2)
Scraped:							
10 years	N	81.5	13.5	4.2	0.8	-	6.4
	E	35.3	37.3	24.8	2.7	-	2.5
	P	60.0	20.0	20.0	-	-	0.1
	A	-	-	-	-	-	0.0
20 years	N	80.0	20.0	-	-	-	0.5
	E	69.6	21.7	8.7	-	-	6.1
	P	-	-	-	-	-	-
	A	100.0	-	-	-	-	0.2
Pilings:							
10 years	N	50.2	32.5	14.0	3.3	-	7.5
	E	42.3	27.8	19.4	8.3	2.4	5.4
	P	31.0	37.2	27.9	3.1	0.7	0.8
	A	90.0	10.0	-	-	-	0.3
20 years	N	71.2	12.3	12.3	4.2	-	2.0
	E	54.0	16.0	18.0	9.0	3.0	2.5
	P	24.0	28.0	40.0	8.0	-	0.7
	A	9.2	27.6	32.2	27.6	4.6	0.8
Undisturbed	N	11.0	4.0	7.0	18.0	61.0	0.5
	E	24.0	20.0	7.0	9.0	39.0	0.9
	P	35.0	12.0	15.0	8.0	31.0	0.2
	A	1.0	3.0	0.0	12.0	84.0	0.5

* N = *Nothofagus cunninghamii*, E = *Eucryphia lucida*, P = *Phyllocladus asplenifolius*, A = *Athrotaxis selaginoides*.

logs that there is a marked increase in the proportion of the upper height classes (table 3).

Phyllocladus is virtually absent from the scraped environment and maintains its density and increases its proportion of the upper height classes on the pilings environment (table 2). On the 20-year site it is only found in quadrats with substantial cover of moss and/or logs, although it is present on all ground cover types on the 10-year site (table 3).

Athrotaxis was the only species to have a higher density on the 20-year than on the 10-year site. The increase of density is concentrated on the pilings environment (table 2) where bare ground and/or moss cover are strongly associated with seedling establishment (table 3). The increase in density and size of the seedlings suggests that establishment is low but continuous and that mortality is low.

DISCUSSION

Twenty years after logging the areas scraped to subsoil by bulldozers show little promise of a restoration of the forest canopy. Although *Eucryphia* is present in substantial density on such sites there is no evidence of successful establishment beyond the small seedling stage. *Nothofagus*, at much lower densities, presents a similar picture, and *Phyllocladus* and *Athrotaxis* are virtually absent. The explanation for this lack of success of seedling regeneration probably lies largely in the nature of the substratum. The almost total lack of organic content in the soil must hinder nutrient adsorption, reduce moisture absorption and reduce the development of pedality. Poor aeration and

TABLE 3

SPECIES REGENERATION:
height class distribution and mean density in groundcover types.

Ground Cover	Logging Period	Tree Species*	Height Classes (m) 0-0.1	0.1-0.2	0.2-0.4	>0.4	Mean density (m^2)
Moss	10 years	N	65.4	21.0	9.6	4.0	10.8
		E	38.3	31.7	22.7	7.4	5.6
		P	42.9	38.1	19.0	-	0.6
		A	100.0	-	-	-	0.3
	20 years	N	71.7	10.0	10.0	8.3	1.6
		E	58.5	30.7	12.5	3.5	4.0
		P	20.0	40.0	40.0	-	0.3
		A	20.0	30.0	20.0	30.0	0.4
Ferns	10 years	N	21.5	42.9	35.8	-	4.6
		E	16.3	46.5	32.5	4.8	4.8
		P	100.0	-	-	-	0.2
		A	-	-	-	-	0.0
	20 years	N	-	-	-	-	0.0
		E	35.3	11.7	35.3	17.7	1.0
		P	-	-	-	-	0.0
		A	50.0	-	50.0	-	0.3
Logs	10 years	N	48.4	22.6	22.6	6.4	3.8
		E	25.0	55.0	15.0	5.0	2.4
		P	28.4	39.8	27.3	4.2	0.7
		A	80.0	20.0	-	-	0.4
	20 years	N	-	100.0	-	-	0.8
		E	66.6	-	20.0	13.4	2.2
		P	23.8	28.6	38.2	9.2	1.2
		A	-	33.0	33.0	33.0	0.5
Gahnia grandis	10 years	N	42.9	42.9	14.3	-	1.7
		E	11.5	30.8	46.2	11.5	2.9
		P	20.0	20.0	60.0	-	0.3
		A	-	-	-	-	0.0
	20 years	N	100.0	-	-	-	0.6
		E	42.9	-	57.1	-	0.7
		P	-	-	-	-	0.0
		A	-	-	-	-	0.0
Bare ground	10 years	N	48.6	38.4	11.9	1.2	3.8
		E	41.3	27.5	21.2	10.0	4.5
		P	36.8	36.8	26.4	-	0.7
		A	75.0	25.0	-	-	0.2
	20 years	N	68.4	15.8	15.8	-	1.6
		E	54.3	13.5	15.3	16.9	2.1
		P	-	-	-	-	0.0
		A	12.5	12.5	37.5	37.8	0.4

*N = *Nothofagus cunninghamii*, E = *Eucryphia lucida*, P = *Phyllocladus asplenifolius*, A = *Athrotaxis selaginoides*.

drainage result from the lack of organic matter, compaction during the logging process and the high clay content of the subsoil. The lack of even a partial canopy cover increases microclimatic fluctuations. These conditions may ameliorate in the long term with a drift of litter from the adjacent forest and pilings and the observed expansion of the cover of moss and *Gahnia grandis*. However, substantial local cover of *Gahnia* appears to preclude the establishment of all tree species. *Gahnia* survives under the low light conditions of

rainforest unburnt for centuries and readily forms a closed-tussock sedgeland where rainforest has been burnt or otherwise disturbed. Where this vegetation type has become established through fire or other disturbance there is no subsequent tree invasion, *Eucryphia* only being present with *Gahnia* when other ground cover types covered a substantial area of a quadrat. As the scraped areas constitute 10-30% of the forest from which timber has been extracted the long term productivity of the forest must be seriously reduced.

The topsoil and logging debris of the pilings environment have proved suitable for the establishment and survival of individuals of all four species, and stocking is such that a restoration of the rainforest canopy seems virtually certain in the absence of fire. The data suggest that the four species differ in their patterns of establishment and mortality on the pilings. *Athrotaxis* lies at one extreme with a low but apparently continuous pattern of establishment and an apparently low mortality rate. The other gymnosperm, *Phyllocladus*, exhibits a less pronounced version of the same patterns. *Eucryphia* and *Nothofagus*, the two angiosperm species, have apparently high and continuous establishment rates and extremely high apparent mortality rates.

The growth rates of the four species, all of which are utilizable for their timber, are extremely low. The most valuable species, *Athrotaxis*, has been shown by ring counts to take 300 years to reach diameters at breast height of 0.3-0.4 m in a stand at 750 m on Mt Read (Ogden 1978a). Ring counts of seedlings on the pilings indicate that *Eucryphia* and *Nothofagus* seedlings 0.4-0.8 m tall fall into the range of 6-9 rings. *Phyllocladus* seedlings vary from 7-11 rings for the same height class and *Athrotaxis* seedlings vary from 8-12 rings. The faster growing species are probably both shorter-lived than the slower-growing gymnosperms. The maximum recorded age of *Nothofagus* is 450-500 years (Gilbert 1959), although Jackson (1968) suggests that its normal lifespan is approximately 350 years. The maximum recorded age for *Phyllocladus* is 780 (?-900) years and for *Athrotaxis* is 900 (-1300) years (Ogden 1978b). No data are available for *Eucryphia*. The period taken for growth to a size utilisable for timber probably varies in order from shortest to longest from *Eucryphia* through *Nothofagus* and *Phyllocladus* to *Athrotaxis*, and there is little doubt that the growth rate of *Athrotaxis* is an order of magnitude slower than that of the two angiosperm species on most sites below 800 m.

The fire ecology of the four species is correlated with their relative longevities and growth rates. *Athrotaxis* is killed by all fires except those of the lowest intensity and flame height. Seed is held in cones on the tree only during late summer and early autumn (Ogden 1978a) and heavy seeding occurs only once in every five or six years (Orme, pers. comm.). The seeds are viable for only three to four months (Orme, pers. comm.). Thus, regeneration after fire can and does occur, but is more the exception than the rule. Where isolated trees are spared by fire most seedlings occur within a radius of 30 m from the parent tree, making recolonization an extremely slow process. Large areas of *Athrotaxis* forest have been completely destroyed by fire in western Tasmania since white settlement (Kirkpatrick 1977a).

Phyllocladus is as fire sensitive as *Athrotaxis*. However, the seed is surrounded by a white fleshy aril and may be dispersed by birds. Isolated trees and seedlings of *Phyllocladus* are often found remote from the nearest possible parent and the species is found widely in forests that have originated after wildfire. Thus, although almost invariably being killed by fire and having seeds of equally short viability period and tenure on the tree, *Phyllocladus* more rapidly recolonizes suitable sites than *Athrotaxis*.

Both *Eucryphia* and *Nothofagus* are capable of vegetative recovery from firing, although mortality is usually high. Both species shed seed in late summer-early autumn, the light winged seeds of *Eucryphia* being better adapted to dispersal than those of *Nothofagus*.

Given the high fire susceptibility of the dominant species of the *Athrotaxis-Nothofagus* closed-forest, their slow growth rates to merchantable size, and the increased chances of ignition and spread of fire provided by the opening up of the canopy and the extension of inflammable vegetation types such as *Gahnia grandis* tussock sedgeland after logging, great care will need to be taken to ensure that the forests in the study area will

be capable of producing another crop. However, if human sources of ignition can be excluded, a difficult task given the easy accessibility now provided by a maze of logging and mining exploration roads, lightning fires are sufficiently infrequent to allow the survival of most of the remaining forest in the area.

The logging methods used in the last twenty years seem inappropriate in a context of sustained yield. On the more fertile basalt soils of the rainforests in northwestern Tasmania similar methods may result in adequate regeneration on logging tracks, but even there would seem undesirable in their encouragement of accelerated erosion. The restriction of bulldozers to tracks constructed from felled cull saplings and small trees as in similar forests in Argentina would seem to present the most desirable alternative to the present methods, as the logs would both prevent the loss of the organic-rich topsoil and would provide a suitable substratum for seedling establishment.

ACKNOWLEDGEMENTS

We wish to express our thanks to the many persons at all levels in the Tasmanian Forestry Commission who provided advice, aid and information for this study.

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TWO NEW NOTOCOTYLID TREMATODES FROM BIRDS IN TASMANIA AND THEIR LIFE HISTORIES

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(with twelve tables and eight text-figures)

ABSTRACT

SMITH, S.J. & HICKMAN, J.L., 1983 (31 viii): Two new notocotylid trematodes from birds in Tasmania and their life histories. *Pap. Proc. R. Soc. Tasm.*, 117: 85-103. ISSN 0080-4703. The Friends' School, Hobart and Department of Zoology, University of Tasmania, Hobart, Australia.

Paramonostomum caeci n. sp., adults of which occur mainly in the intestinal caeca of *Anas superciliosa*, *Cygnus atratus* and *Poliocephalus poliocephalus*, is described. It is considered to closely resemble *P. malerischi* from which it differs in being only one-third the size, having a spinose tegument and a cirrus covered with tubercles. *P. bursae* n.sp., adults of which have been found inhabiting the bursa of Fabricius of *Anas superciliosa* is described and considered to be most similar to *P. alveatum* and *P. parvum* but to differ from them in the distribution of its vitellaria, the position of its ovary relative to the testes and in having a greater number of uterine loops. The domestic duck, *Anas platyrhynchos*, was found to serve as an experimental host for both new species. A brackish water snail, *Coxiella badgerensis*, inhabiting Calverts Lagoon in southeast Tasmania serves as a natural intermediate host for *P. caeci* n.sp. and *P. bursae* n.sp. and also for two other undescribed notocotylids. Developmental stages (rediae, cercariae and metacercariae) of both new *Paramonostomum* species are described. The cercaria of *P. caeci* n. sp. belongs to the Imbricata group, and that of *P. bursae* n.sp. to the Yenchingensis group.

INTRODUCTION

Developmental stages of four species of notocotylid trematodes (subfamily Notocotylinae Kossack, 1911), have been found infecting the gastropod *Coxiella badgerensis* (Johnston) at Calverts Lagoon near Hobart, Tasmania (Smith 1981). The cercariae of these species leave the molluscan host and encyst free in the aquatic environment. Although cysts of each species were fed to laboratory ducklings, the adults of only two species became established. They have been identified as new species of the genus *Paramonostomum* and flukes considered conspecific with them have been found in black duck from the lagoon. Notocotylids identified with one of the species have also been recovered from hoary-headed grebe and black swan which frequent the lagoon.

There have been few reports of notocotylids in birds of the Australasian region: *Catatropis gallinulae* was recorded in the dusky moorhen in South Australia (Johnston 1928); an unidentified notocotylid was recorded in the mallard in Tasmania (Angel, pers. comm. in Munday & Green 1972); and *Uniserialis gippyensis*, *Catatropsis* sp. and *Notocotylus* sp. were recorded in various anatids in New Zealand (Rind 1974). In 1975, specimens of an unidentified notocotylid were found in the black swan at Lake Bookar, Queensland (Smith 1981, pp. 256-257).

Pre-adult stages of notocotylid species are distinguished principally by the form of the excretory ring of mature cercariae, and by the form and size of metacercarial cysts. Rothschild (1938) proposed that notocotylid cercariae be classified into three groups, according to the form of the excretory ring: Imbricata, Yenchingensis and Monostomi. The cercariae of two of the species at Calverts Lagoon belong to the Imbricata group, those of another belong to the Yenchingensis group and those of the fourth species belong to the Monostomi group.

Two Notocotylid Trematodes from Birds in Tasmania

Two of the notocotylid species are described in this paper. Both are named after their habitats in the definitive hosts: *Paramonostomum caeci* n.sp. which inhabits the intestinal caeca, and *P. bursae* n.sp. which inhabits the bursa of Fabricius.

MATERIALS AND METHODS

Individual *Coxiella badgerensis* from Calverts Lagoon were maintained at room temperature in filtered lagoon water and crystal dishes in the laboratory. Snails releasing notocotylid cercariae were either used to provide metacercarial cysts for experimental infection of ducklings or were dissected and examined for trematode developmental stages. Fully developed cercariae encysted on the host snail's shell or on the walls of the crystal dish.

Domestic ducklings, *Anas platyrhynchos* Linnaeus, purchased when one day old from Rutherglen Duck Farm, Rutherglen, Victoria, were maintained in the laboratory and when approximately one week old were fed gelatin capsules containing metacercarial cysts. The ducks were killed with chloroform after periods of up to five weeks. The periods of infection of these experimental hosts are referred to in this paper using an abbreviated style, i.e. 18 days and 23 hours post-infection is given as 18, 23 days P.I.

Two black ducks, *Anas superciliosa* Gmelin, two black swans, *Cygnus atratus* (Latham), and five hoary-headed grebes, *Poliocephalus poliocephalus* (Jardine and Selby), frequenting Calverts Lagoon were shot and taken to the laboratory where dissection was usually begun within four hours of death. When two birds were shot on the same day, one was stored at 5°C and dissected within 24 hours of death. The duck were shot on 27/4/78, the swan on 8/8/78 and the grebes on 31.7.78 (two), 14.8.78 (two) and 5.10.78 (one).

Observations of live trematodes on microscope slides were facilitated by slightly compressing the specimens in Hank's balanced salt solution under coverslips supported by a little vaseline. Specimens were examined under both ordinary and phase contrast light microscopes. Aqueous vital stain solutions 0.001% brilliant cresyl blue and 0.001% neutral red, were used to stain live cercariae.

Some specimens, slightly compressed under coverslip pressure, were relaxed by heating gently over a slide warmer and then fixed by drawing 70% ethanol under the coverslip with filter paper. Most specimens were fixed, without compression, in boiling 10% phosphate buffered formal saline. Generally, after fixation, worms were stained in alum carmine or Gower's carmine. Metacercariae and adults, flattened and fixed in 70% ethanol, were treated with Fast Red Salt B to stain phenolic egg-shell precursors in the vitellaria and vitelline ducts, and usually counterstained in Gower's carmine. Organ primordia, and the various stages of spermatogenesis in metacercariae and juvenile flukes, were detected in aceto-orcein squashes, or whole mounts. Permanent whole mounts of stained specimens were prepared by clearing in clove oil, and mounting in Canada balsam, or D.P.X., via standard procedures. Drawings were made with the aid of a camera lucida.

Unless otherwise stated all measurements are given in microns (mean first, followed by size range in parenthesis) and are based, except in the case of metacercarial cysts, on specimens fixed without compression. Cysts were measured live and uncompressed.

PARAMONOSTOMUM CAECI n.sp.

1. Life cycle (fig. 1)

Cercariae leave the primary intermediate host, *Coxiella badgerensis*, and encyst on its shell and operculum and on other submerged surfaces, such as the valves of ostracods, cuticle of amphipods and possibly plants. The hoary-headed grebe, black swan and black duck serve as definitive hosts.

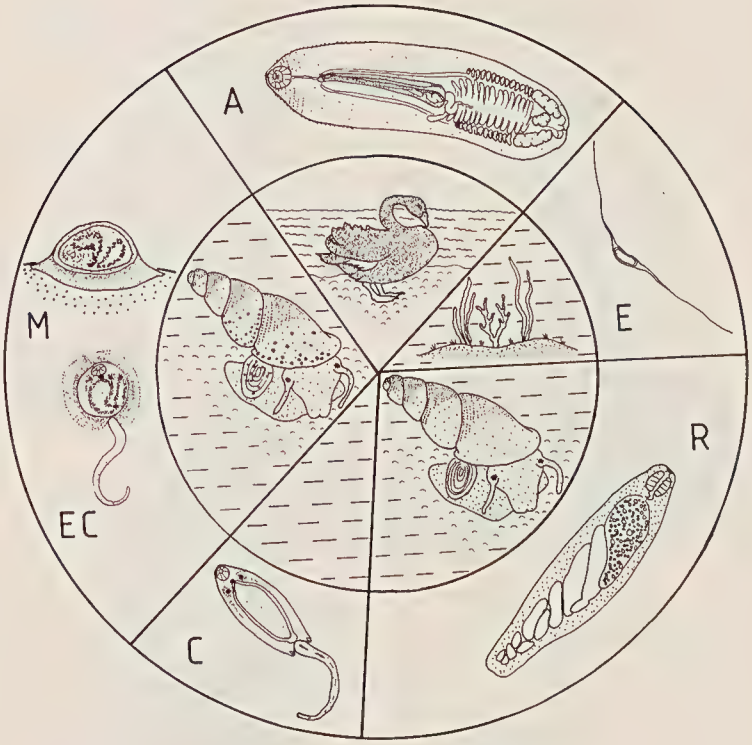

FIG. 1 - *Paramonostomum caeci* n.sp. Life-cycle diagram showing hosts (inner) circle) and parasite stages (outer circle). A: adult; E: egg; R: daughter redia; C: mature cercaria; EC: encysting cercaria; M: metacercarial cyst.

2. Adult (fig. 2)

Unfortunately, gravid specimens recovered from experimentally infected ducklings were all fixed under coverslip pressure. The dimensions of gravid and immature adults from these experimental hosts are shown in table 1. Dimensions of the holotype, and other gravid and immature adults from the hoary-headed grebe, fixed unflattened by standard methods, are shown in table 2.

Description

Dorsoventrally flattened, elongate-spatulate body, margins slightly curled ventrally. Tegumental spines in ventral surface, diminishing in size posteriorly; dorsal surface aspinous. Brown-black pigment dispersed in anterior one-third of body. No ventral glands or glandular ridges. Oral sucker oval, terminal; mouth terminal or subterminal ventral. Pharynx absent; oesophagus short; caeca simple, extending posteriorly between vitellaria and uterine loops, then between ovary and testes, terminating medial to posterior lobes of testes. Excretory ducts ramify throughout body, connecting with closed excretory ring. Excretory bladder large, lobate, opening through dorsal excretory pore. Testes posterolateral, elongate, deeply lobed. Common sperm duct convoluted, expanded serving as external seminal vesicle, entering base of cirrus pouch. Internal seminal vesicle bulbous, sinuous; pars prostatica well-developed, leading to ejaculatory duct within long, slender, coiled cirrus. Everted cirrus, about 171 × 19 µm, covered in small tubercles. Cirrus pouch elongate, clavate, extending from genital pore to near middle of body. Genital pore median, overlying or anterior to oesophageal bifurcation. Ovary lobate, intercaecal, at level of middle to anterior parts of testes. Oviduct short, leading anteriorly to ootype, surrounded by Mehlis' gland. Proximal uterus expanded, serving as seminal receptacle.

TABLE 1

PARAMONOSTOMUM CAECI n.sp. DIMENSIONS OF ADULTS FROM EXPERIMENTALLY INFECTED DUCKLINGS. (a) 2,6 days P.I. (non-ovigerous); and (b) 13,0 days P.I. (ovigerous).

	(a) n = 10		(b)* n = 5	
Body: length	364	(310-416)	1194	(983-1467)
width	157	(144-166)	479	(423-575)
Oral sucker: length	44	(42-49)	81	(76-87)
width	52	(46-53)	89	(80-94)
Oesophagus: length	4	(4-8)	-	
Cirrus pouch: length	-		505	(460-551)
width	-		74	(72-76)
Ovary: length	23	(19-27)	109	(95-129)
width	19	(15-23)	49	(46-57)
Left testis: length	38	(34-42)	173	(163-182)
width	22	(19-23)	89	(87-91)
Right testis: length	40	(38-42)	182	(-)
width	25	(1-38)	87	(84-91)
Body length:body width ratio	2.32		2.49	
Distance from anterior of body to cirrus pouch base:body length ratio	-		0.52	(0.50-0.54)
Distance from posterior of body to anterior of vitellaria:body length ratio	-		0.35	(0.32-0.38)

* fixed under coverslip pressure

TABLE 2

PARAMONOSTOMUM CAECI n.sp. DIMENSIONS OF ADULTS FROM A NATURALLY INFECTED HOARY-HEADED GREBE. (a) ovigerous specimens; (b) non-ovigerous specimens; and (c) dimensions of the holotype, a gravid specimen.

	(a) n = 10		(b) n = 10		(c) n = 1
Body: length	736	(597-907)	475	(333-590)	816
width	189	(151-219)	133	(83-197)	219
Oral sucker: length	53	(46-61)	47	(38-59)	51
width	59	(49-67)	47	(34-55)	57
Oesophagus: length	12	(0-46)	6	(4-8)	53
Cirrus pouch: length	331	(293-395)	224		361
width	33	(30-38)	19		32
Metraterm: length	287	(228-369)	-		312
width	16	(11-19)	-		14
Ovary: length	61	(53-87)	38	(27-49)	57
width	38	(27-42)	23	(19-27)	38
Left testis: length	108	(84-125)	93	(84-103)	110
width	45	(42-49)	40	(38-42)	49
Right testis: length	108	(87-122)	82	(68-95)	122
width	52	(42-65)	46	(42-49)	65
Body length:body width ratio	3.89		3.57		3.73
Distance from anterior of body to cirrus pouch base:body length ratio	0.55	(0.52-0.58)	-		0.56
Distance from posterior of body to anterior of vitellaria:body length ratio	0.37	(0.33-0.42)	-		0.39

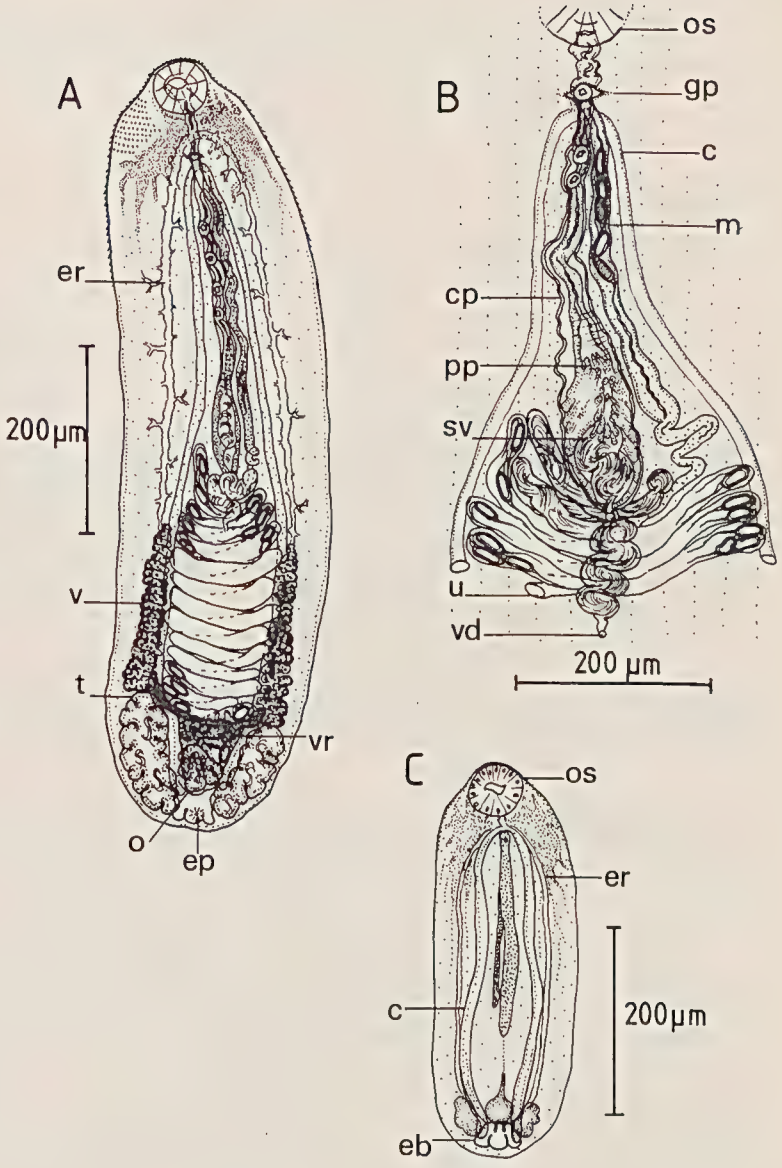

FIG. 2 - *Paramonostomum caeci* n.sp. A: gravid adult from hoary-headed grebe, ventral view; B: flattened gravid adult, after 13 days in laboratory duckling, detail of cirrus pouch region, ventral view; C: immature adult, after 2,6 days in laboratory duckling, dorsal view (c: caecum; cp: cirrus pouch; eb: excretory bladder; ep: excretory pore; er: excretory ring; gp: genital pore; m: metraterm; o: ovary; os: oral sucker; pp: pars prostatica; sd: sperm duct; sv: seminal vesicle; t: testis; u: uterus; v: vitellaria; vr: vitelline receptacle).

Uterus initially passing posteriorly, then forming 12-14 transverse loops between transverse vitelline ducts and cirrus pouch. Metraterm well-developed, opening with cirrus pouch at ventral genital pore. Ratio of length of metraterm to length of cirrus pouch = 0.9. Vitelline glands extracaecal, longitudinal, extending from testes to two-fifths body length from posterior end of body, never reaching middle of body. Vitelline ducts transverse, uniting between caeca, forming sinistral vitelline reservoir, which leads posteriorly to ootype, anteromedial to ovary. Hundreds of large eggs occupying uterus of gravid adult.

Two Notocotylid Trematodes from Birds in Tasmania

Vertebrate hosts

Anas platyrhynchos L. (experimental host); *A. superciliosa* Gmelin; *Cygnus atratus* (Latham); and *Poliocephalus poliocephalus* (Jardine and Selby).

Habitat

Mainly intestinal caeca, also lower small intestine and rectum.

Geographic location

Calverts Lagoon, southeast Tasmania.

Type material

Tasmanian Museum - K907, holotype (ringed), gravid adult; K907, paratypes (not ringed), gravid adults; K908, K909, K910 and K911, paratypes, adults.

Relationships

Paramonostomum caeci n.sp. clearly belongs to the *elongatum* group of Harwood (1939) and is most similar to the group of species: *P. elongatum, P. bucephalae* and *P. malerischi*, that Stunkard (1967) said were characterised by "linear, spatulate bodies, very long cirrus sacs that extend to the middle of the body, and short vitelline zones". From the position of the genital pore, overlying or anterior to the oesophageal bifurcation, and the relatively large eggs, *P. caeci* n.sp. appears closest to *P. malerischi*, a fluke inhabiting the caeca of the Emperor goose, *Philacte canagica*, in Alaska (Dunagan 1957). Apart from the major difference in size (*P. malerischi* is more than three times longer than the longest specimen of *P. caeci* n.sp.), the tegument of *P. malerischi* is aspinous and its cirrus in "unarmed", whereas the tegument of *P. caeci* n.sp. bears spines in the anterior ventral region, and its cirrus is covered with distinct tubercles.

Biology

Cysts varying in age from 11 to 42 days, were found to be infective to laboratory ducklings. Four out of nine ducklings became infected with from one to twenty-eight flukes. Up to 80% of metacercariae were recovered as adults, all of them living in the intestinal caeca. The adults are established in the caeca after 22 hours and can live there for at least 13 days.

This fluke naturally inhabits the caeca, and is sometimes also found in the lower small intestine and rectum of several bird species at Calverts Lagoon. One out of two black ducks harboured seven adults; two out of two black swans harboured 20 and 70 adults and five out of five hoary-headed grebes were heavily infected, each harbouring hundreds of adults.

The metacercaria undergoes considerable growth and development within the experimental bird host. After 2,6 days the genital primordia can be distinguished, and by 5,3 days eggs are being formed and occupy the proximal 11 loops of the uterus. After 13,0 days, the adult has grown considerably and eggs occupy 12 to 14 uterine loops. Adults removed from an experimentally infected duckling after 13,0 days, were maintained *in vitro* at 41°C for 2 days in 40% foetal calf serum in Eagles' M.E.M. Large numbers of eggs were shed into the culture medium.

3. Egg (figs 3A, 3B)

The operculate egg is without filaments when formed and is oblong to reniform in shape. Long polar filaments develop as it passes through the uterus, one filament forming at each end of the egg. The egg-shell is transparent, colourless and uniform in thickness, except where it thins at the operculum rim. Miracidial development was discernible within the egg after 3 days in lagoon water. No eggs had hatched after 6 days under normal light and temperature conditions. Ten uninfected snails, *Coxiella badgerensis*, were fed eggs but were found not to be infected when dissected 49 days later. Live eggs measure about 26 × 11 µm, and polar filaments extend up to 333 µm. Dimensions of fixed eggs (not including the polar filaments), are shown in table 3.

TABLE 3

PARAMONOSTOMUM CAECI n.sp. DIMENSIONS OF UTERINE EGGS IN ADULT FLUKES. (a) from a naturally infected hoary-headed grebe; and (b) *from an experimentally infected duckling, 13,0 days P.I.

Host	Number of eggs	Length	Width
(a)	10	25 (23-29)	11 (8-14)
(b)	10	26 (24-27)	12 (11-12)

* flukes fixed under coverslip pressure

4. Redia (fig. 3C)

The rediae are more or less cylindrical to sausage-shaped, maximum width occurring near the middle and minimum width occurring at the posterior end. They range in size from very small individuals containing only germ balls, to the largest, containing germ balls and immature cercariae. The tegument is transparent and colourless, however the intestine appears brown-black, due to contained decomposing snail tissue. A terminal mouth opens into a large, barrel-shaped, muscular pharynx. A short sinuous oesophagus leads to the simple intestine, which is about one-half the body length in small rediae, but becomes relatively shorter as cercariae develop in the "brood chamber". Cercariae leave the redia through a birth pore situated at the mid-level of the pharynx and complete their growth and development free in the snail tissues.

The number of rediae found per infected snail, varied from 11 to 38. They occurred throughout the host's viscera, but were concentrated in the hepatopancreas. Dimensions of daughter rediae are shown in table 4.

TABLE 4

PARAMONOSTOMUM CAECI n.sp. DIMENSIONS OF DAUGHTER REDIAE. Fifteen rediae selected at random

Body: length	597 (257-696)
width	160 (129-189)
Pharynx: length	66 (61-76)
width	62 (55-68)

5. Cercaria (fig. 4)

The body of this monostome cercaria is broadly oval to elongate, slightly concave ventrally. The tegument is speckled with numerous minute papillae, or spines. The tail is simple, usually longer than the body. Both the body and tail are very contractile. The tail, joined to the body by a slender peduncle, is attached terminally or slightly posterodorsally. The peduncle is flanked by two eversible, posterolateral locomotory appendages, each with an adhesive sucker or gland at its tip. A narrow excretory duct extends about three-quarters of the length of the tail. A round to oval oral sucker protrudes anteriorly. The mouth is subterminal ventral, surrounded by a ring of about 32 ciliated papillae. The oesophagus bifurcates posterior to the lateral eyespots, forming simple caeca which extend to the level of the excretory bladder. The parenchyma is packed, from the mid-level of the oral sucker to the excretory bladder, with unicellular cystogenous glands about 11 µm diameter, each filled with bacilliform rods about 2-3 µm long.

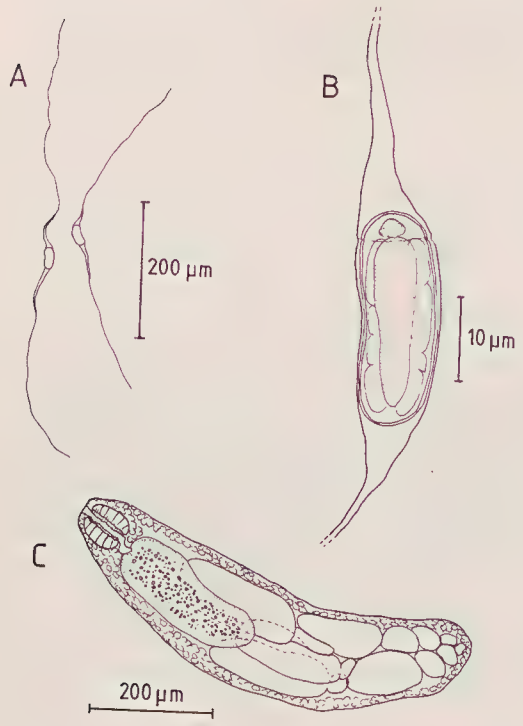

FIG. 3 - *Paramonostomum caeci* n.sp.
A: eggs deposited *in vitro* by fluke from experimentally infected duckling;
B: detail of similar egg after 3 days in lagoon water at room temperature;
C: daughter redia.

These glands make the body relatively opaque and obscure the anatomy. The excretory ring can only be seen when the body is flattened. It is of the Imbricata type, having an anterior loop that extends anteriad to the cerebral ganglion, overlapping, and sometimes extending anterior to the median eyespot. The ring is without diverticula and contains excretory granules, 5-8 µm diameter, along its length. There are about 4 granules across the posterior part of the ring, where it is about 20 µm wide, and from 1 to 3 granules across the anterior extremity of the ring, where it is only about 10 µm wide. The lateral eyespots are oval to round, composed of densely packed black pigment granules. The median eyespot is annular, composed of more dispersed brown pigment granules. This pigment is also distributed in dendritic strands around, and extending posteriad from, the lateral eyespots.

Under natural light and temperature conditions, mature cercariae emerged from the snail host between dawn and midday. Under controlled conditions, emergence occurred when the host snail was exposed to bright light, following a period of darkness. When snails were kept in constant darkness, no cercariae emerged. Free-swimming cercariae are positively phototactic, and in the laboratory swam near the water surface, encysting within an hour of emergence from the primary host. Although some cercariae encysted on the snail shell, most encysted on the side of the glass container. The cercariae swam an erratic course, the body leading and the tail describing the infinity symbol in the vertical plane.

Dimensions of the cercaria are shown in table 5.

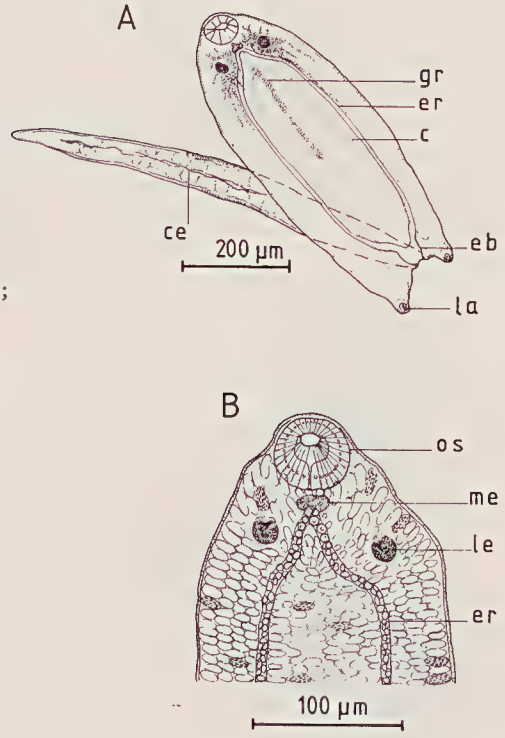

FIG. 4 - *Paramonostomum caeci* n.sp. A: cercaria, dorsal view; B: flattened cercaria, detail of anterior region, ventral view (c: caecum; ce: caudal excretory duct; eb: excretory bladder; er: excretory ring; gr: genital rudiment; la: locomotory appendage; le: lateral eyespot; me: median eyespot; os: oral sucker).

TABLE 5

PARAMONOSTOMUM CAECI n.sp. DIMENSIONS OF MATURE CERCARIAE. Fifteen cercariae measured after emergence from *Coxiella badgerensis*.

Body: length	534 (454-612)
width	165 (166-197)
depth	109 (91-144)
Tail: length	655 (499-771)
width	54 (45-68)
Oral sucker: length	47 (42-53)
width	49 (46-51)
depth	48 (44-51)
Eyespot diameter	17 (15-19)

6. Metacercaria (fig. 5A)

When the cercaria stops swimming it creeps briefly, pauses, and then encystment commences. Cystogenous glands secrete bacilliform granules through the tegument, forming a flimsy outer cyst, which adheres to the substrate. The body contracts into a round shape and slow rhythmic contractions pass anteriorly along it. After a few minutes the body moves independently within the initial cyst wall. At this time the tail breaks free and swims away. The body rotates back and forth, as more cystogenous secretions are added internally to the cyst wall. The mature cyst is more or less hemispherical, with a thin flange around the base. Adherence to the substrate is by this peripheral flange, not by the basal cyst wall. The enclosed metacercaria appears light brown, with darker stripes, due to the conspicuous granular excretory ring.

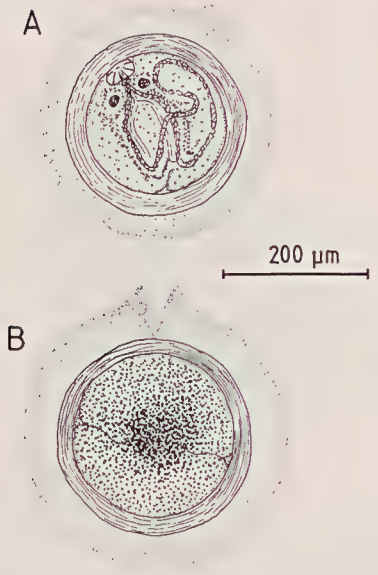

FIG. 5 - Notocotylid metacercarial cysts, plan view.
A: *Paramonostomum caeci* n.sp.
B: *Paramonostomum bursae* n.sp.

The cysts formed by cercariae from the same snail are similar in size, however there is variation between cysts formed by cercariae from different snails. Dimensions of metacercarial cysts are shown in table 6.

TABLE 6

PARAMONOSTOMUM CAECI n.sp. DIMENSIONS IN PLAN VIEW OF METACERCARIAL CYSTS. Cysts formed by cercariae from two different snails.

	(a) n = 5	(b) n = 5
Interior: length	191 (186-194)	198 (194-201)
width	192 (190-194)	195 (190-201)
Exterior: length	253 (247-258)	252 (247-258)
width	255 (251-262)	248 (243-255)
Basal flange: length	306 (300-312)	327 (319-346)
width	310 (304-323)	304 (—)

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PARAMONOSTOMUM BURSAE n.sp.

1. Life-cycle

The life-cycle of *P. bursae* n.sp. is similar to that of *P. caeci* n.sp. (fig. 1). Cercariae, on leaving the primary intermediate host *Coxiella badgerensis*, encyst on the shell and operculum of the snail and on other submerged surfaces, such as plant stems. The black duck serves as the definitive host.

2. Adult (figs 6A and 7)

Dimensions of immature adults and mature adults with a few incomplete eggs, fixed by standard methods, from experimental hosts, are shown in table 7. Unfortunately gravid adults containing hundreds of fully formed eggs, from both experimental hosts and the black duck, were fixed under coverslip pressure. One such gravid adult from a laboratory duckling is designated as the holotype, and its dimensions are shown, with those of other gravid flukes, in table 8.

Description

Body oval to pyriform, flattened, leaf-like; margins sometimes folded ventrally. Tegument aspinous. Black-brown pigment grains distributed extensively in anterior region No ventral glands or glandular ridges. Oral suck round terminal; mouth terminal or subterminal ventral; pharynx absent; oesophagus short. Caeca simple convoluted, extending posteriorly between vitellaria and uterus, then between ovary and testes, terminating posterior to testes. Excretory ducts anastomose throughout body, from excretory ring. Excretory bladder lobate, opening through dorsal excretory pore. Testes lobate, posterolateral. Common sperm duct convoluted, expanded, serving as external seminal vesicle, entering proximal end of cirrus pouch. Internal seminal vesicle leading via well-developed pars prostatica to ejaculatory duct, within cirrus. Everted cirrus, elongate, about 300 × 35 µm, covered in large tubercles. Cirrus pouch clavate, extending posteriorly from genital pore to between one-third and two-fifths body length from anterior end of body. Genital pore median, immediately posterior to oesophageal bifurcation. Ovary lobate, sub-median dextral, inter-caecal; mid-level of ovary anterior to mid-level of testes; ovary usually extending anterior to testes, never posterior. Oviduct short, passing posterolateral to ootype, surrounded by median Mehlis' gland. Proximal uterus serving as seminal receptacle. Uterus convoluted, forming 12 to 15 transverse, intercaecal loops. Metraterm opening with cirrus pouch at ventral genital pore. Ratio of length of metraterm to cirrus pouch length from 0.6 to 0.8. Vitelline glands extra-caecal, longitudinal, extending from testes to middle of body. Vitelline ducts transverse, uniting to form longitudinal vitelline reservoir, which leads posteriorly to ootype. Hundreds of relatively large eggs occupying uterus of gravid adult.

Vertebrate hosts

Anas platyrhynchos L. (experimental host), *A. superciliosa* Gmelin.

Habitat

Bursa of Fabricius.

Geographical position

Calverts Lagoon, southeast Tasmania.

Type material

Tasmanian Museum - K912, holotype, gravid adult (flattened); K913, paratypes, gravid adults (flattened); K914 and K915, paratypes, immature adults.

Relationships

The broad, oval to pyriform body of *Paramonostomum bursae* n.sp. is characteristic of the *alveatum* group of the genus (Harwood 1939), however unlike many species of this shape, the vitellaria do not extend anteriad as far as the cirrus pouch, and do not extend

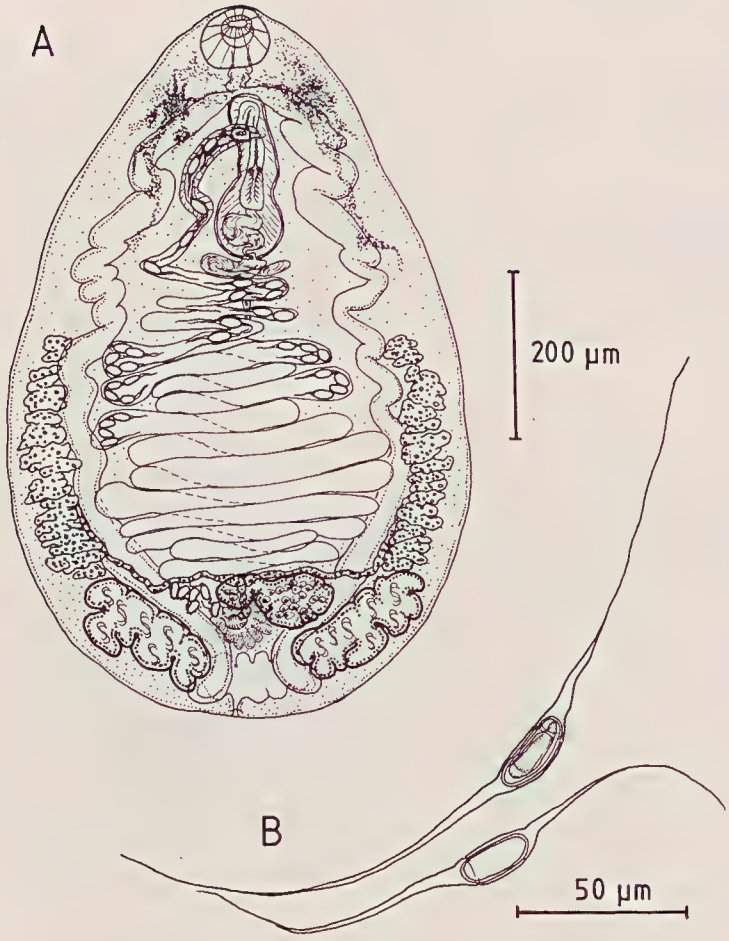

FIG. 6 - *Paramonostomum bursae* n.sp.
A: holotype, flattened gravid adult, from laboratory duckling 9 days after infection, dorsal view;
B: eggs deposited *in vitro* by fluke taken from wild black duck.

into the anterior third of the body. In morphology and anatomy *P. bursae* n.sp. appears most similar to *P alveatum* and *P. parvum*. Like these species, it has a relatively short cirrus pouch, which extends only up to two-fifths body length from the anterior end of the body. It differs from both of these species, however, in the distribution of vitellaria. In *P. alveatum* and *P. parvum*, vitellaria extend into the anterior one-third of the body, according to Stunkard (1967). The position of the ovary also differs, being dextral and extending anterior to the testes in *P. bursae* n.sp.; and median, at the level of the posterior part of the testes in *P. alveatum* and *P. parvum*. The number of uterine loops of *P. bursae* n.sp. is 12-15, and that of *P. alveatum* and *P. parvum* is 10-12. *P. alveatum* and *P. parvum* inhabit the lumen of the intestine of ducks in North America (Stunkard & Dunihue 1931, Stunkard 1967) and *P. alveatum* also occurs in anatids in Europe (Yamaguti 1971). *P. bursae* n.sp. inhabits the bursa of Fabricius of ducks at Calverts Lagoon. The cercariae of *P. alveatum* and *P. parvum* are of the Monostomi type (Stunkard 1967), whereas the cercaria of *P. bursae* n.sp. is of the Yenchingensis type.

TABLE 7

PARAMONOSTOMUM BURSAE n.sp. DIMENSIONS OF ADULTS FROM EXPERIMENTALLY INFECTED DUCKLINGS. (a) 2,12 days P.I.; and (b) 5,3 days P.I. with newly formed eggs, lacking filaments, in the proximal uterus.

	(a) n = 15		(b) n = 4	
Body: length	443	(378-537)	764	(756-771)
width	181	(136-212)	314	(295-333)
Oral sucker: length	49	(46-53)	68	(67-68)
width	49	(46-51)	70	(68-72)
Oesophagus: length	58	(57-61)	49	(38-61)
Cirrus pouch: length	-		192	(171-213)
width	-		53	(49-57)
Metraterm: length	-		148	(144-152)
width	-		23	(-)
Ovary: length	-		60	(53-67)
width	-		72	(-)
Left testis: length	38	(-)	97	(87-103)
width	38	(34-42)	95	(87-103)
Right testis: length	47	(38-53)	108	(106-110)
width	38	(34-46)	105	(103-106)
Body length:body width ratio	2.45		2.43	

TABLE 8

PARAMONOSTOMUM BURSAE n.sp. DIMENSIONS OF GRAVID ADULTS.*
(a) from an experimentally infected duckling 9,0 days P.I.;
(b) from a naturally infected black duck; and (c) dimensions of the holotype, taken from (a).

	(a) n = 5		(b) n = 10		(c) n = 1
Body: length	650	(469-832)	1338	(953-1648)	832
width	416	(318-544)	764	(605-907)	544
Oral sucker: length	56	(49-65)	95	(76-106)	65
width	74	(72-80)	114	(87-129)	80
Cirrus pouch: length	151	(95-201)	267	(156-327)	201
width	62	(46-80)	103	(68-114)	80
Metraterm: length	152		169	(125-239)	152
width	27		37	(30-42)	27
Ovary: length	48	(38-61)	133	(76-182)	61
width	84	(76-95)	151	(122-198)	95
Left testis: length	127	(99-179)	208	(148-266)	171
width	60	(49-72)	164	(114-228)	68
Right testis: length	117	(80-171)	211	(148-239)	186
width	61	(49-76)	165	(129-209)	76
Body length:body width ratio	1.56		1.75		1.53
Distance from anterior of body to cirrus pouch base:body length ratio	0.38	(0.35-0.39)	0.35	(0.29-0.39)	0.36
Distance from posterior of body to anterior of vitellaria:body length ratio	0.53	(0.51-0.55)	0.55	(0.50-0.61)	0.52

* fixed under coverslip pressure

Biology

Cysts from 2-24 days old proved to be infective to laboratory ducklings. Up to about 60% of metacercariae were recovered as adults, and every adult inhabited the bursa of Fabricius. Five out of eight ducklings that were exposed to infection, harboured adults of *P. bursae* n.sp. From two to 24 adult worms were recovered from each infected bird. The maximum longevity of *P. bursae* n.sp. in the laboratory duckling was 9,0 days. One of two wild black ducks shot at Calverts Lagoon was infected with 16 adult *P. bursae* n.sp., all of which inhabited the bursa of Fabricius.

Considerable growth and development occurs within experimentally infected ducklings. After 1,23 days, the adult has reached the bursa of Fabricius. Its body is small and elongate and genital primordia are barely discernible. Black pigment is still concentrated in the regions of the cercarial eyespots. After 2,12 days, the body is broader and more pyriform, black pigment is dispersed in the anterior region, and the gonads and cirrus pouch have developed. The juvenile fluke nearly doubles in size over the next 3 days (fig. 7). At 5,3 days post-infection the reproductive system is fully developed, and egg production has commenced. At 9,0 days the uterus is filled with hundreds of eggs. Adults of *P. bursae* n.sp. are usually found deeply buried in the plicate lining of the bursa of Fabricius, their presence revealed by superficial white patches in the otherwise pink host tissue. When not buried, the dark anterior pigmentation makes the flukes conspicuous.

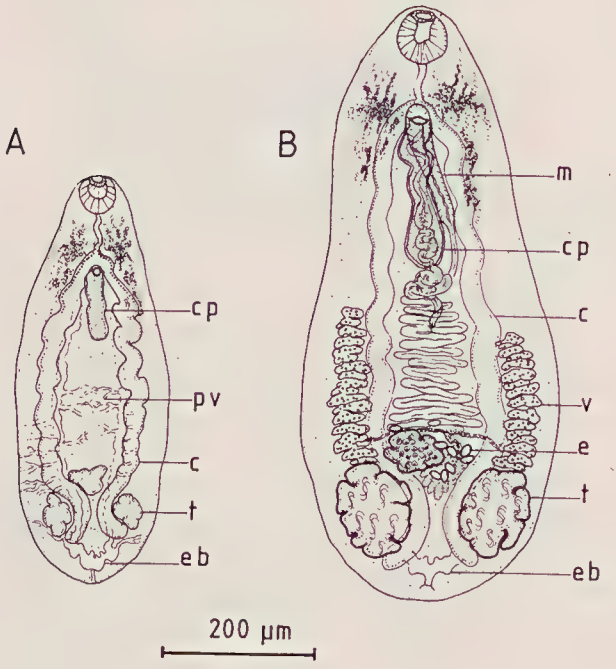

FIG. 7 - *Paramonostomum bursae* n.sp.
A: juvenile adult, after 2,12 days in laboratory duckling, ventral view;
B: mature adult with incompletely formed eggs in the proximal uterus, after 5,3 days in laboratory duckling, ventral view.
(c: caecum; cp: cirrus pouch; e: egg; eb: excretory bladder; m: metraterm; pv: paranephridial vessels; t: testis; v: vitellaria).

3. Eggs (fig. 6B)

The operculate egg, like that of *P. caeci* n.sp., is formed without polar filaments. Filaments form as the clear, colourless egg passes through the uterus. Dimensions of uterine eggs, not including the polar filaments, are shown in table 9. They are markedly smaller than those of *P. caeci* n.sp. Polar filaments are about 114 µm long.

TABLE 9

PARAMONOSTOMUM BURSAE n.sp. DIMENSIONS OF UTERINE EGGS IN FLUKES.*
(a) from an experimentally infected duckling, 9,0 days P.I.; and
(b) from a naturally infected black duck.

Host	Number of eggs	Length	Width
(a)	10	20 (19-21)	11 (8-11)
(b)	10	21 (18-23)	11 (10-12)

* flukes fixed under coverslip pressure

Miracidial development was evident in the egg after two days in lagoon water at room temperature, under normal light conditions. No eggs had hatched after 30 days under these conditions. Eggs incubated in lagoon water for two days were fed to ten laboratory-bred snails, *Coxiella badgerensis*. Five snails were dissected after 34 days, and five after 69 days; however, none were infected.

4. Redia (fig. 8A)

Rediae are cylindrical to sausage-shaped, maximum width occurring in the anterior one-third of the body. The terminal mouth opens into a relatively small pharynx and a short convoluted oesophagus leads to the simple intestine, which in larger specimens is filled with black-brown, granular, decomposing snail tissue. The gut becomes relatively shorter as the redia grows. Immature cercariae emerge through a birth pore lateral to the pharynx.

Rediae are found throughout the host viscera, mainly in the hepatopancreas. In one snail, 18 rediae were found, eight relatively mature specimens containing germ balls and developing cercariae, and ten immature specimens containing only germ balls. Dimensions of daughter rediae are shown in table 10.

TABLE 10

PARAMONOSTOMUM BURSAE n.sp. DIMENSIONS OF DAUGHTER REDIAE.
Ten daughter rediae selected at random.

Body: length	803 (544-953)
width	194 (151-257)
Pharynx: length	51 (38-61)
width	54 (38-61)

5. Cercaria (figs 8B and 8C)

Mature cercariae are similar in morphology and anatomy, but slightly larger than, those of *Paramonostomum caeci* n.sp. The tegument is speckled with minute papillae, or spines. Two lateral eyespots are composed of dense concentrations of black pigment grains. A third, median eyespot is composed of more dispersed brown pigment grains, which are extensively distributed in dendritic strands around the eyespots and extend posteriorly,

dorsal to the excretory ring. The tail is simple and attached terminally, between posterolateral, locomotory appendages. A caudal excretory duct extends through the middle of the tail, flanked by six pairs of large cells, which are stained intensely by neutral red. The round oral sucker protrudes slightly anteriorly; the mouth is terminal to subterminal ventral, encircled by a ring of prominent sensory papillae. The oesophagus and caeca are developed and the body densely packed with round cystogenous glands, containing bacilliform granules up to 5 µm long. The distinguishing characteristic of this cercaria is the excretory ring of the Yenchingensis type. It has a large single anterior diverticulum, that arises between the lateral eyespots and extends anterior to the median eyespot, sometimes as far as the oral sucker. The excretory ring is packed with granules which increase in diameter anteriorly from 5-11 µm. There are about four grains across the ring near the excretory bladder, and only one or two across the anterior part of the ring and diverticulum.

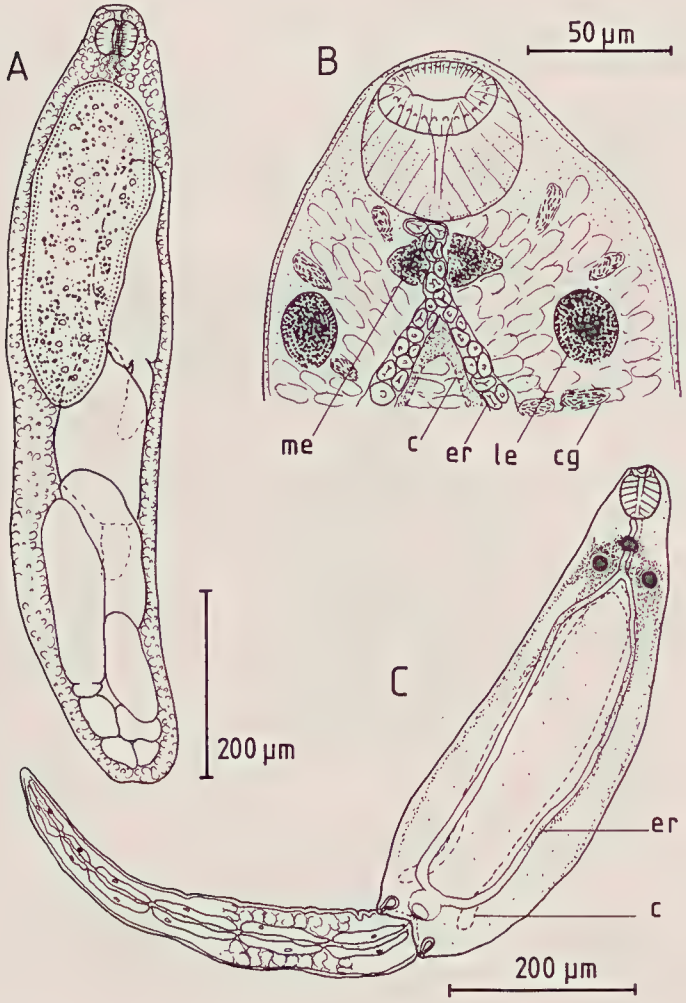

FIG. 8 - *Paramonostomum bursae* n.sp.
A: daughter redia;
B: flattened cercaria, detail of anterior region, ventral view;
C: cercaria, dorsal view. (c: caecum; cg: cystogenous gland; er: excretory ring; le: lateral eyespot; me: median eyespot).

In the laboratory, mature cercariae emerged from the snail host during mid-morning. After a variable period of swimming, from about 1-60 minutes, the positively phototactic cercariae encysted on the sides of the glass container, or on the host's shell and operculum. Dimensions of the cercaria are shown in table 11.

TABLE 11

PARAMONOSTOMUM BURSAE n.sp. DIMENSIONS OF MATURE CERCARIAE.
Fifteen cercariae measured after emergence from the snail host.

Body: length	534 (408-620)
width	180 (163-201)
depth	147 (106-179)
Tail: length	650 (559-786)
width	58 (49-65)
Oral sucker: length	51 (49-57)
width	46 (38-49)
depth	49 (—)
Eyespot diameter	24 (21-27)

6. Metacercaria (fig. 5B)

Encystment occurs in the same manner as described for *P. caeci* n.sp. The cyst is more or less hemispherical, with a thin basal flange. It is round, in plan view, with a markedly greater diameter than that of the cyst of *P. caeci* n.sp. The cyst contents of *P. bursae* n.sp. appear uniformly dark brown, and almost opaque, whereas those of *P. caeci* n.sp. appear striped, due to the translucent light brown parenchyma and opaque excretory ring. Dimensions of metacercarial cysts are shown in table 12.

TABLE 12

PARAMONOSTOMUM BURSAE n.sp. DIMENSIONS IN PLAN VIEW OF METACERCARIAL CYSTS.
Cysts formed by cercariae from two different snails.

	(a) n = 5	(b) n = 4
Interior: length	214 (209-220)	224 (220-228)
width	215 (209-224)	220 (213-228)
Exterior: length	—	280 (270-285)
width	—	282 (274-289)
Flange: length	345 (342-350)	365 (361-372)
width	350 (342-372)	367 (361-376)

DISCUSSION

Infection of one snail species by a number of notocotylid trematodes has been previously recorded. Rothschild (1941) reported a five-year study of the infection of *Peringia ulvae* Pennant in England by six notocotylid species. Three of the species belonged to the Yenchingensis group and three to the Monostomi group. Stunkard (1967) reported the discovery of five notocotylid species infecting *Hydrobia salsa* in the U.S.A. One of the species belonged to the Imbricata group, two to the Yenchingensis group and two to the Monostomi group.

Although the life-cycles of two of the notocotylids at Calverts Lagoon, *Paramonostomum caeci* n.sp. and *P. bursae* n.sp., have been elucidated, further studies are needed to identify another two notocotylid species that infect *Coxiella badgerensis* at the lagoon.

Rothschild (1941) found that two species of the Yenchingensis group developed into adults of the genus *Paramonostomum*, in the intestinal caeca of ducks. Stunkard (1967) found that the cercariae of *P. alveatum* and *P. parvum*, belong to the Monostomi group, and that the corresponding adults inhabit the lumen of the intestine of their bird host. Velasquez (1969) reported that the cercaria of *P. philippinensis* is of the Yenchingensis group, although his description and illustration indicate that it belongs to the Imbricata group. The adult of this species inhabits the intestinal caeca of the bird host. At Calverts Lagoon, the cercaria of *P. caeci* belongs to the Imbricata group, and the adult inhabits the intestinal caeca of ducks, whereas that of *P. bursae* n.sp. belong to the Yenchingensis group, and the adult inhabits the bursa of Fabricius of ducks. The cercariae of species currently classified in the genus *Paramonostomum*, thus belong to the Imbricata, Yenchingensis and Monostomi groups. Odening (1966) reported that the cercariae of five *Notocotylus* species belonged to the Monostomi group, whereas Stunkard (1960, 1966) found that the cercariae of two *Notocotylus* species belonged to the Yenchingensis group. A cercaria of the Yenchingensis group (Szidat & Szidat 1933) and one of the Monostomi group (Yamaguti 1938) are reported to develop into the same adult, *Notocotylus attenuatus*.

The apparent lack of correlation between cercarial types and notocotylid genera raises some doubts about the current classification within the family *Notocotylidae*. In his review of the genus *Paramonostomum*, Stunkard (1967) emphasized the importance of the discovery of life-cycles and the description of larval stages, to the taxonomy of the *Notocotylidae*. The present studies add support to that view.

ACKNOWLEDGEMENTS

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Papers and Proceedings of the Royal Society of Tasmania, Volume 117, 1983.

(ms. received 4.6.1982)

THREE NEW SPECIES AND A NEW RECORD OF MICROPHALLID TREMATODES FROM TASMANIA, WITH OBSERVATIONS ON THEIR *IN VITRO* DEVELOPMENT.

by S.J. Smith
The Friends' School, Hobart

(with nine tables and six text-figures)

ABSTRACT

SMITH, S.J., 1983 (31 viii): Three new species and a new record of microphallid trematodes from Tasmania, with observations on their *in vitro* development. *Pap. Proc. R. Soc. Tasm.*, 117: 105-123. ISSN 0080-4703. The Friends' School, Hobart, Tasmania, Australia.

Four species of microphallid trematodes occurring as metacercariae in the estuarine crab *Paragrapsus gaimardii* (M. Edw.) at Great Bay, Bruny Island, Tasmania, are described from specimens excysted and cultured to maturity *in vitro*. *Gynaecotyla hickmani* n.sp., and *G. macrocotylata* n.sp., occur in the green gland and body cavity, *Maritrema eroliae* Yamaguti, 1939 occurs in the body cavity and *Microphallis paragrapsi* n.sp. inhabits the nervous system of the crab.

INTRODUCTION

In 1968 Dr P.S. Lake, who at that time was a lecturer in the Department of Zoology, University of Tasmania, was engaged in neuro-endocrinological studies on the crab *Paragrapsus gaimardii* (M. Edw.) when he found in histological sections what he concluded were cysts of a parasite. He submitted the material to his colleague Dr J.L. Hickman who identified them as trematode cysts. On subsequent investigation *P. gaimardii* from Great Bay, Bruny Island, Tasmania, were found to be infected with metacercarial cysts of four microphallid species: *Gynaecotyla hickmani* n.sp., *G. macrocotylata* n.sp., *Maritrema eroliae* Yamaguti, 1939 and *Microphallus paragrapsi* n.sp.

The Tasmanian vertebrate and molluscan hosts of these trematodes have not yet been discovered. The following descriptions of the four species are based mainly on adults obtained *in vitro* by culturing excysted metacercariae to maturity.

MATERIALS AND METHODS

The estuarine crab *Paragrapsus gaimardii* was collected at low tide, from under rocks at Great Bay, Bruny Island, and maintained in running seawater in a marine aquarium for up to two weeks prior to dissection. Crabs were examined for trematodes in seawater, in plastic petri dishes. They were prepared for dissection by pithing, and then removal of limbs at the basi-ischium/merus joint, using strong scissors. The carapace was cut around the margins of the dorsal surface, and removed. Internal organs were first examined *in situ* under a dissecting microscope and then removed for further examination. The location of any trematodes present was recorded.

Metacercarial cysts were dissected free of host tissue, washed twice in isotonic saline and then transferred for excystment to test-tubes containing either 0.5% pancreatin or 0.5% pancreatin and 0.2% sodium taurocholate, dissolved in Hank's Balanced Salt Solution (Hank's BSS), gassed with CO_2 to pH 7.4 and pre-heated to 41 ± 1°C. The test-tubes were shaken for 30 seconds overy 15 minutes for a period of 60 minutes in an intermittently shaking water-bath kept at 41 ± 1°C. The trematodes were then rinsed free of the enzyme with Hank's BSS and maintained in Hank's BSS in the water-bath for a further 60 minutes. Excystment occurred in the enzyme solution and in the saline.

Observations on live excysted metacercariae were facilitated by slightly compressing specimens under coverslips supported by a little vaseline. For measurement, some excysted

metacercariae were fixed without flattening in boiling 10% phosphate buffered formol saline. Such worms were generally stained in alum carmine or Gower's carmine. Some excysted metacercariae and adults, flattened and fixed in 70% ethanol, were treated with Fast Red Salt B to stain phenolic egg-shell precursors in the vitellaria and vitelline ducts, and usually counter-stained in Gower's carmine. Permanent whole amounts of stained worms were prepared by clearing in clove oil, and mounting in Canada balsam, via standard procedures.

Some excysted metacercariae were cultured *in vitro*. Routine *in vitro* culture procedures were carried out under sterile conditions inside a laminar flow cabinet, using sterile culture media (Hank's BSS, Eagle's MEM and foetal calf serum), supplied by the Commonwealth Serum Laboratories. Serum was inactivated before use, by heating for one hour in a water-bath at 56°C. Excysted metacercariae were transferred to a sterile Universal vial at 41°C, and given four sterile washes of 10 minutes each in Hank's BSS before being transferred to the culture medium (Eagle's MEM, or Eagle's MEM plus 20% or 40% foetal calf serum) in a sterile Leighton tube. Cultures were maintained in an intermittently shaking (30 seconds every 13 minutes) water-bath at 41 ± 1°C. The pH of cultures was held at 7.4 by periodic gassing with 5% CO_2 in air.

Some metacercarial cysts of each microphallid species were placed in gelatine capsules and force fed to approximately one-week old uninfected ducklings, *Anas platyrhynchos* Linnaeus. The ducklings were killed with chloroform after periods of up to 5 weeks, dissected and examined for trematodes.

In the following descriptions, unless otherwise stated, all measurements are given in microns (the mean first, followed by the size range in parenthesis) and are based, except in the case of metacercarial cysts, on specimens fixed without compression. Cysts were measured live and uncompressed. Drawings were made with the aid of a camera lucida.

GYNAECOTYLA HICKMANI n.sp.

1. Adult

Dimensions of relatively mature, non-ovigerous, unflattened excysted metacercariae are shown in table 1. The adult is illustrated in fig. 1 and is described below from ovigerous adults obtained by *in vitro* culture of excysted metacercariae. Dimensions of unflattened ovigerous adults are not available.

Description

Body spatulate, dorsoventrally flattened, maximum width usually at level of gonads. Tegumental spines quincuncially arranged, extending to level of testes, diminishing in size posteriorly. Tegumental glands distributed over anterior body. Oral sucker round, mouth subterminal ventral. Prepharynx about one-quarter length of oesophagus. Pharynx oval, oesophagus bifurcates in anterior half of body. Caeca relatively short, terminating at or before mid-level of testes. Antiporal ventral sucker much larger, more muscular than weakly developed poral ventral sucker. Testes posterolateral, oval, symmetrical. Vesiculoprostatic pouch arcuate, between caeca, partly dorsal to antiporal ventral sucker. Large sausage-shaped seminal vesicle occupies proximal seven-eights; pars prostatica short, opening through ejaculatory orifice, between fleshy lobes of cornucotyle. Cornucotyle intermediate in size between ventral suckers, smaller than oral sucker. Lobes of cornucotyle side by side in same plane: outer lobe 40(38-42) × 14(11-15)µ, large, smooth; inner lobe smaller, 30(27-34) × 21(19-23)µ, surface studded with conical protuberances. Thin sclerotized layer, about 22 × 1µ, lines inner surface of outer lobe. Muscle fibres extend from posterior margin of vesiculoprostatic pouch to base of cornucotyle. Ovary round sinistral, between antiporal ventral sucker, sinistral testis, sinistral caecum. Oviduct short, passing posteromedially to ootype, posterior to ventral suckers. Uterus forms initial anterior loop, then looping posterior to testes. Metraterm enters genital atrium dorsally, opening adjacent to ejaculatory orifice. Vitelline glands clustered in distinct post-testicular groups. Vitelline ducts large, arising in centre of each group, passing anteromedially to small vitelline reservoir, ventral to ootype. Uterine eggs numerous, measuring 20(17-23) × 10(8-11)µ, (fixed, flattened). Flame-cell formula not determined. Excretory vesicle typical of genus, resembling Cross of Lorraine.

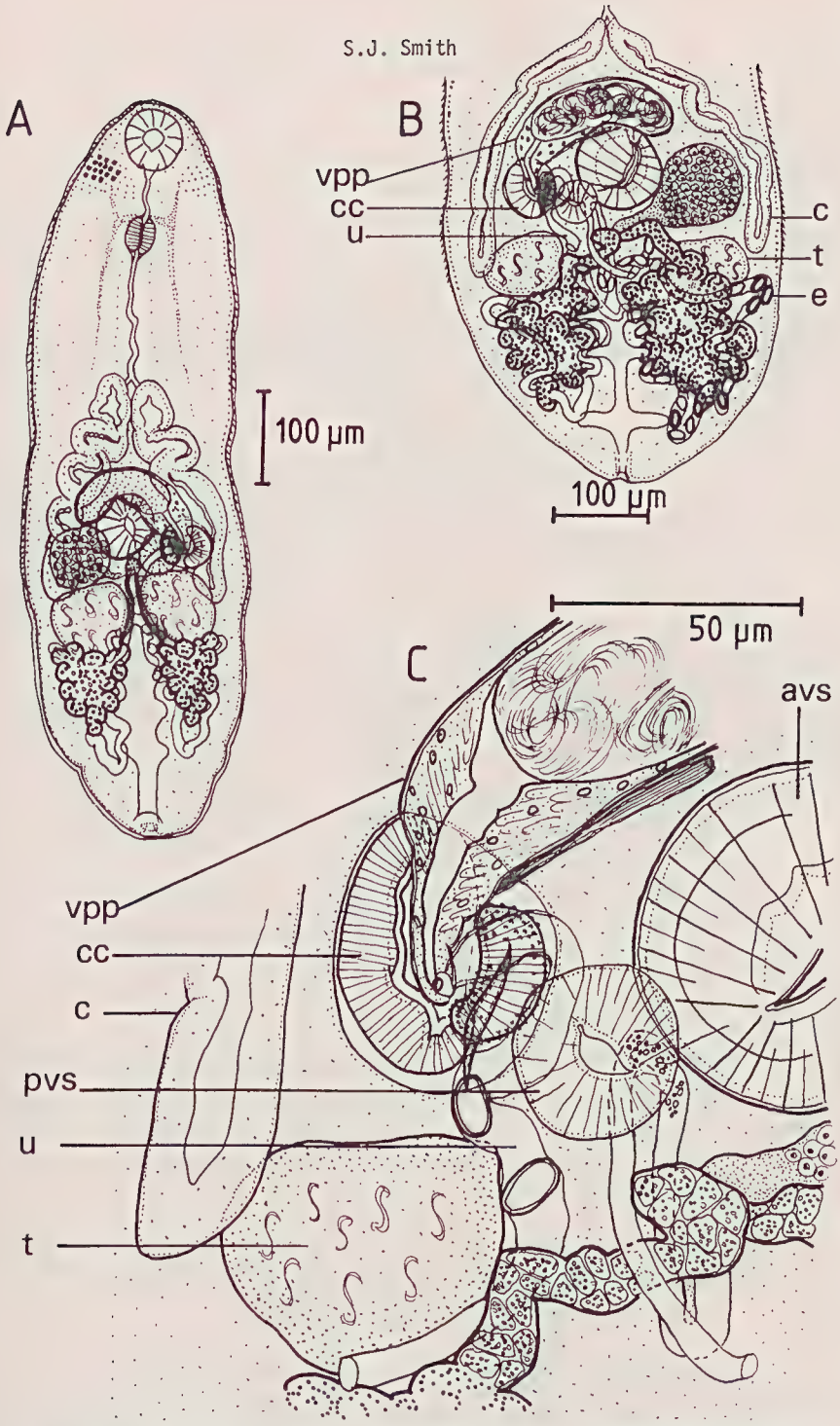

FIG. 1 - *Gynaecotyla hickmani* n.sp. A: holotype, mature excysted metacercariae after 12 hours at 41°C, dorsal view; B: slightly flattened gravid adult, ventral view; C: detail from B, of cornucotyle region. (avs: antiporal ventral sucker, c: caecum, cc: cornucotyle, e: egg, pvs: poral ventral sucker, t: testis, u: uterus, vpp: vesiculoprostatic pouch).

Crustacean intermediate host
Paragrapsus gaimardii (M. Edw.).

Geographical location
Great Bay, Bruny Island, Tasmania.

Site of encystment
Green gland, general body cavity.

Type material
Tasmanian Museum and Art Gallery - K895 holotype, mature excysted metacercaria (ringed); K896 paratypes, gravid adults (flattened); K897 and K898 paratypes, mature excysted metacercariae.

TABLE 1

EXCYSTED METACERCARIAE OF *GYNAECOTYLA HICKMANI* n.sp.
Dimensions of metacercariae excysted *in vitro:*
(a) after about 3 hours at 41°C, and (b) the holotype, after 12 hours at 41°C. All specimens relatively mature with active vitallaria, but no eggs.

	(a) n = 20	(b) n = 1
Body:length (BL)	735 (582-839)	703
width	220 (190-255)	217
Oral sucker:length (OS)	54 (48-61)	54
width	54 (49-61)	48
Prepharynx:length	43 (23-57)	38
Oesophagus:length	156 (118-190)	129
Pharynx:length	38 (34-42)	34
width	29 (25-32)	27
Left caecum:length	264 (220-304)	232
Right caecum:length	264 (224-304)	234
Antiporal ventral sucker:length (AVS)	69 (61-84)	68
width	65 (53-80)	65
Poral ventral sucker:length (PVS)	43 (38-48)	42
width	36 (32-40)	40
Cornucotyle:length (C)	44 (38-49)	42
width	46 (42-49)	-
Vesiculoprostatic pouch:length (VPL)	122 (106-148)	137
width	35 (30-40)	34
Ovary:length	60 (49-67)	72
width	53 (46-61)	63
Left testis:length	85 (63-99)	89
width	66 (53-84)	74
Right testis:length	81 (68-91)	91
width	63 (42-80)	68
VPL:BL ratio	0.17	0.19
Relative size (l+w) of organs	AVS > OS > C > PVS	

2. Metacercarial cyst (fig. 2)

The large round cyst occurs mainly in the green gland, but also in the body cavity of *Paragrapsus gaimardii*, either free or loosely bound by connective tissue. The cyst wall, about 28 μ thick, is composed of a wide translucent outer layer, often yellowish, and a narrow, clear inner layer. Dimensions of 20 cysts, their identity confirmed by *in vitro* excystment, are shown in table 2.

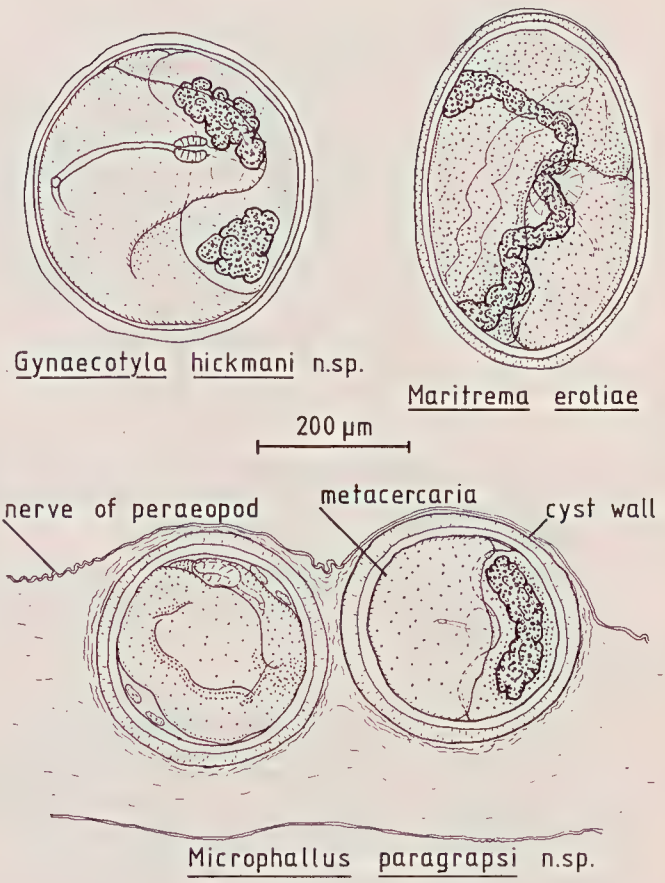

FIG. 2 - Trematode cysts infecting the crab *Paragrapsus gaimardii*. The cysts of *Gynaecotyla hickmani* n.sp. and *Maritrema eroliae* are shown free in the body cavity. Cysts of *Microphallus paragrapsi* n.sp. are embedded in a large nerve from the coxa of a peraeopod.

Metacercariae excyst at varying stages of maturity from those in which sex organs are not well developed, to those in which gametogenesis and vitellogenesis are advanced. Eggs are produced by more advanced specimens after one day in Eagle's MEM plus 20% foetal calf serum at 41°C.

TABLE 2

CYSTS OF *GYNAECOTYLA HICKMANI* n.sp.
Dimensions of live metacercarial cysts
dissected from naturally infected
Paragrapsus gaimardii (n=20).

External dimensions	length	416 (378-514)
	width	396 (348-499)
Internal dimensions	length	359 (334-384)
	width	342 (315-365)

3. Relationships

This new species of *Gynaecotyla* is named after Dr J.L. Hickman, in recognition of his initial investigations of the microphallids infecting the crab *P. gaimardii* at Great Bay. Using the key to species of the genus *Gynaecotyla*, proposed by Deblock (1974), *G. hickmani* n.sp. keys out with *G. brisbanensis* Deblock & Pearson, 1968a, and *G. bridgmani* Deblock, 1974. It is distinctly larger than both of those species, and although similar in shape and general anatomy, differs from them in several respects. The sclerotized pieces in the cornucotyle of *G. bridgmani*, arranged like a Y, are quite distinct. The form and ornamentation of the cornucotyle of *G. brisbanensis* are similar to those of *G. hickmani* n.sp. The arc of the vesiculoprostatic pouch of *G. brisbanensis* is not subtended by bundles of muscle fibres, and the diameter of the oral sucker is greater than or equal to the diameter of the antiporal ventral sucker; however, the vesiculoprostatic pouch of *G. hickmani* n.sp. is subtended by conspicuous muscle fibres, extending from the pouch to the cornucotyle, and the antiporal ventral sucker is much larger than the oral sucker.

GYNAECOTYLA MACROCOTYLATA n.sp.

1. Adult

A minority of *Gynaecotyla* metacercariae that excysted *in vitro* from large, round cysts taken from the body cavity of *Paragrapsus gaimardii*, were obviously different from *Gynaecotyla hickmani* n.sp., and were found to belong to another new species, *Gynaecotyla macrocotylata* n.sp.

Dimensions of relatively mature, non-ovigerous, unflattened excysted metacercariae of this species are presented in table 3. The adult, illustrated in figure 3, is described from ovigerous specimens cultured *in vitro*. Dimensions of the unflattened ovigerous holotype are included in table 3.

Description

Body elongate spatulate. Tegumental spines diminish in size posteriorly, extending to level of testes. Tegumental gland cells distributed in anterior of body. Oral sucker round, mouth subterminal ventral. Prepharynx about one-quarter length of oesophagus, pharynx oval; oesophagus bifurcates in anterior half of body. Caeca long, convoluted, terminating posterior to testes. Two ventral suckers well developed, antiporal ventral sucker slightly larger than poral ventral sucker. Testes posterolateral, oval, symmetrical. Vesiculoprostatic pouch arcuate, partly dorsal to ventral suckers, between caeca. Seminal vesicle occupies proximal two-thirds; pars prostatica opens through ejaculatory orifice, into genital atrium. Cornucotyle larger than oral and ventral suckers. External lobe largely ventral, enveloping smaller internal lobe, measures about 91 × 48 µ. Internal lobe measures about 47 × 42 µ. Surfaces of lobes smooth except for scattered small pointed projections. Three sclerotized pieces on, partly embedded in, anterior part of cornucotyle: according to scheme of Deblock (1974, p.323), no.2 elongate bent obliquely in middle, about 32 × 10 µ; no.5 rod shaped, about 20 × 7 µ; no.6 forked, about 17 × 8 µ. Two bundles of well developed muscles extend from piece no.6 to posterior wall of vesiculoprostatic pouch. Ovary round, sinistral, situated between sinistral testis and proximal end of vesiculoprostatic pouch, partly dorsal to antiporal ventral sucker. Oviduct passes posteromedially to median ootype. Uterus forms loops posterior to testes, then passes anteriad to genital atrium. Metraterm enters atrium dorsally, opening near ejaculatory orifice. Vitelline glands clustered in two distinct post-testicular bunches. Vitelline ducts pass anteriad, joining to form small round median vitelline reservoir. Eggs numerous, measure 17(16-19) × 12(11-13) µ (fixed, flattened). Flame-cell formula not determined. Excretory vesicle typical of genus.

Crustacean intermediate host

Paragrapsus gaimardii (M. Edw.).

Geographical location

Great Bay, Bruny Island, Tasmania.

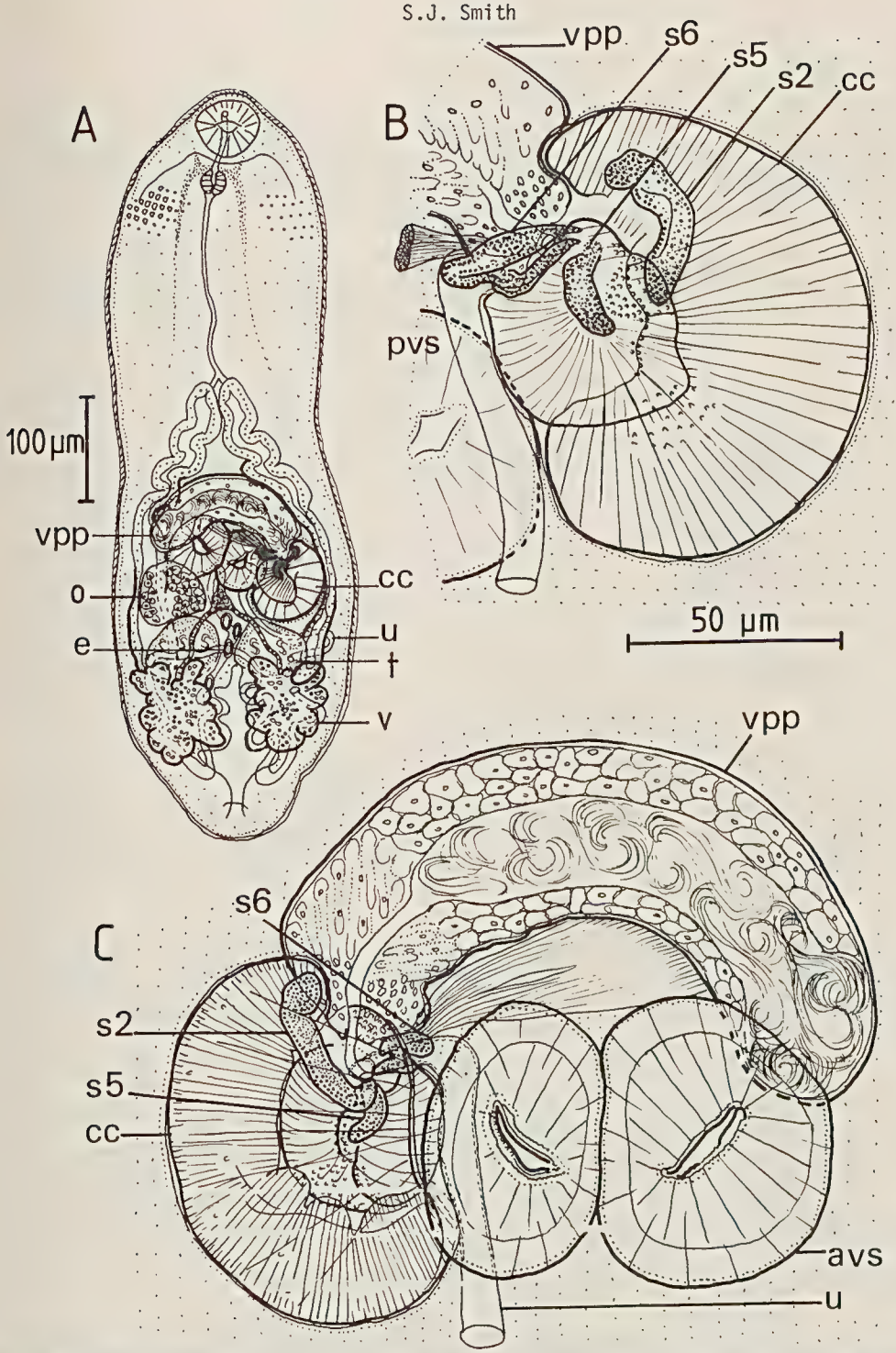

FIG. 3 - *Gynaecotyla macrocotylata* n.sp. A: holotype, gravid adult, dorsal view; B: flattened gravid adult, detail of cornucotyle, dorsal view; C: gravid adult, detail of vesiculoprostatic pouch and ventral suckers, ventral view. (avs: antiporal ventral sucker, cc: cornucotyle;, e: egg, o: ovary, pvs: poral ventral sucker, s2, s5, s6: sclerotized pieces in cornucotyle, t: testis, u: uterus, v: vitellaria, vpp: vesiculoprostatic pouch).

Site of encystment
Green gland, general body cavity.

Type material
Tasmanian Museum and Art Gallery - K899 holotype, gravid adult (ringed); K900 paratypes, gravid adults (flattened); K901 and K902 paratypes, mature excysted metacercariae.

TABLE 3

EXCYSTED METACERCARIAE OF *GYNAECOTYLA MACROCOTYLATA* n.sp.
Dimensions of; (a) mature, non-ovigerous specimens after about 3 hours *in vitro* at 41°C, and (b) the holotype, a gravid specimen, after about 12 hours *in vitro* at 41°C.

	(a) n = 12	(b) n = 1
Body:length (BL)	779 (665-937)	703
width	238 (224-258)	227
Oral sucker:length (OS)	55 (49-61)	48
width	56 (53-61)	53
Prepharynx length	44 (34-57)	38
Oesophagus length	201 (160-228)	160
Pharynx:length	40 (36-44)	36
width	30 (27-32)	27
Left caecum length	323 (289-372)	285
Right caecum length	329 (296-380)	308
Antiporal ventral sucker:length (AVS)	68 (61-74)	68
width	59 (53-68)	57
Poral ventral sucker:length (PVS)	63 (57-68)	61
width	46 (42-51)	48
Cornucotyle:length (C)	78 (65-95)	84
width	71 (68-72)	72
Vesiculoprostatic pouch:length (VPL)	166 (156-182)	160
width	45 (42-49)	46
Ovary:length (O)	65 (57-72)	70
width	57 (53-61)	61
Left testis:length	70 (65-80)	68
width	57 (51-65)	53
Right testis:length	66 (61-72)	65
width	58 (49-65)	53
VPL:BL ratio	0.21	0.23
Relative size (l+w) of organs	C > AVS > PVS ≃ OS	

2. Metacercarial cyst

The cysts are round and large, and occur mainly in the green gland, but also in the general body cavity of *Paragrapsus gaimardii*. To date they have not been distinguished from those of *G. hickmani* n.sp. In January 1980, about 50 large, round metacercarial cysts from the body cavity of *P. gaimardii* were measured, and then exposed to digestive enzymes *in vitro*, however all of the metacercariae that excysted were *G. hickmani* n.sp. In December 1979, similar, unmeasured cysts were exposed to digestive enzymes *in vitro*, and the ratio of the two *Gynaecotyla* species in 100 excysted metacercariae was 85 *G. hickmani* n.sp. to 15 *G. macrocotylata* n.sp.

The metacercaria of *G. macrocotylata* n.sp. excysts at varying stages of maturity. The more advanced specimens, with active vitellaria producing phenolic egg-shell precursors, become ovigerous after one day in Eagle's MEM plus 20% foetal calf serum at 41°C.

3. Relationships

The more distinct differences between *G. macrocotylata* n.sp. and *G. hickmani* n.sp. are that in the former the cornucotyle is larger than the oral and ventral suckers, the two ventral suckers are similar in muscular development, the poral ventral sucker is similar in size to the oral sucker, the cornucotyle contains three large sclerotized pieces, and the caeca are relatively long, terminating posterior to the testes; whereas in *G. hickmani* n.sp. the cornucotyle is smaller than the oral sucker and antiporal ventral sucker, the antiporal ventral sucker is more powerfully developed than the poral ventral sucker, the cornucotyle contains only a single thin sclerotized layer, and the caeca do not extend posterior to the testes.

According to the key to the species of *Gynaecotyla* presented by Deblock (1974), *G. macrocotylata* n.sp. most closely resembles the large form of *G. longiintestinata* Leonov, 1958 (syn. *G. gallica* Rebecq, 1961). In the latter species, however, the oral sucker is larger than the poral ventral sucker, and larger than or equal to the antiporal ventral sucker. The form and arrangement of sclerotized pieces in the cornucotyle, which are consistent within *Gynaecotyla* species, differ markedly between *G. macrocotylata* n.sp. and *G. longiintestinata*, e.g. in the latter species no.6 is not branched, and no.2 is absent, whereas in the former, no.6 is forked, and no.2 is well developed.

The name *G. macrocotylata* n.sp. is proposed for this new species as the cornucotyle is massive, and both ventral suckers are large and muscular.

MARITREMA EROLIAE YAMAGUTI, 1939

Syn. (according to Deblock, 1975): *M. urayensis* Ogata, 1951; *M. magnicirrus* Belopolskaia, 1952; *M. kitanensis* Shibue, 1953.

1. Adult

The adult, illustrated in figure 4, is described from ovigerous specimens cultured *in vitro*, and from one gravid fluke recovered from a laboratory duckling. Dimensions of mature excysted metacercariae, some of which have commenced egg production, are shown in table 4. Ovigerous and non-ovigerous specimens are similar in size.

Dimensions

Body elongate pyriform to triangular. Tegumental spines small, cover entire body, except at posterior extremity. Tegumental gland cells anterior to cirrus pouch. Oral sucker round. Prepharynx about half length of oesophagus; pharynx oval; oesophagal bifurcation about one-third body length from anterior end. Caeca diverge acutely, extend to midlevel of metraterm. Ventral sucker round, larger than oral sucker, located in posterior half of body. Oval testes symmetrical, situated posterolaterally. J-shaped cirrus pouch massive, about 2.5 µ thick. Flexure of pouch antero-dorsal to ventral sucker. Seminal vesicle large, clavate, in proximal half of dextral limb of cirrus pouch. Distal end of seminal vesicle tapers to short, narrow, folded seminal canal, which widens to voluminous, convoluted pars prostatica. Invaginated spiny cirrus leads from level of anterior seminal vesicle to sinistral genital atrium, proximal part of cirrus densely lined by simple sharp spines, increasing in size distally from 5 × 2 µ to 10 × 3 µ; distal part lined by large, flattened, thorn-like spines, variable in size, 12 (6-19) × 7 (5-10) µ. Evaginated cirrus, directed anteriorly, about 150 µ long, (fixed flattened), with small simple spines covering distal part, increasing in size to several rows of thorn-like spines near base of cirrus. Aspinous 'heel' at base of evaginated cirrus. Ovary triangular, multilobed (usually three main lobes), median, dorsal to ventral sucker, bounded anteriorly by cirrus pouch, posteriorly by metraterm. Oviduct leads posteriorly to median ootype, surrounded by well-developed Mehlis' gland. Uterus loops around each testis, mainly lying within vitelline ring; enters vast, muscular metraterm medially, posterior to ovary. Metraterm lining about 13 µ thick, traversed by radial fissures which widen towards lumen. Eggs numerous, oval 18 (16-19 × 9 (8-10) µ. Vitelline glands form post-ovarian ring, closed posteriorly, open near ootype. Vitelline ducts short, transverse, uniting medially to form short longitud-

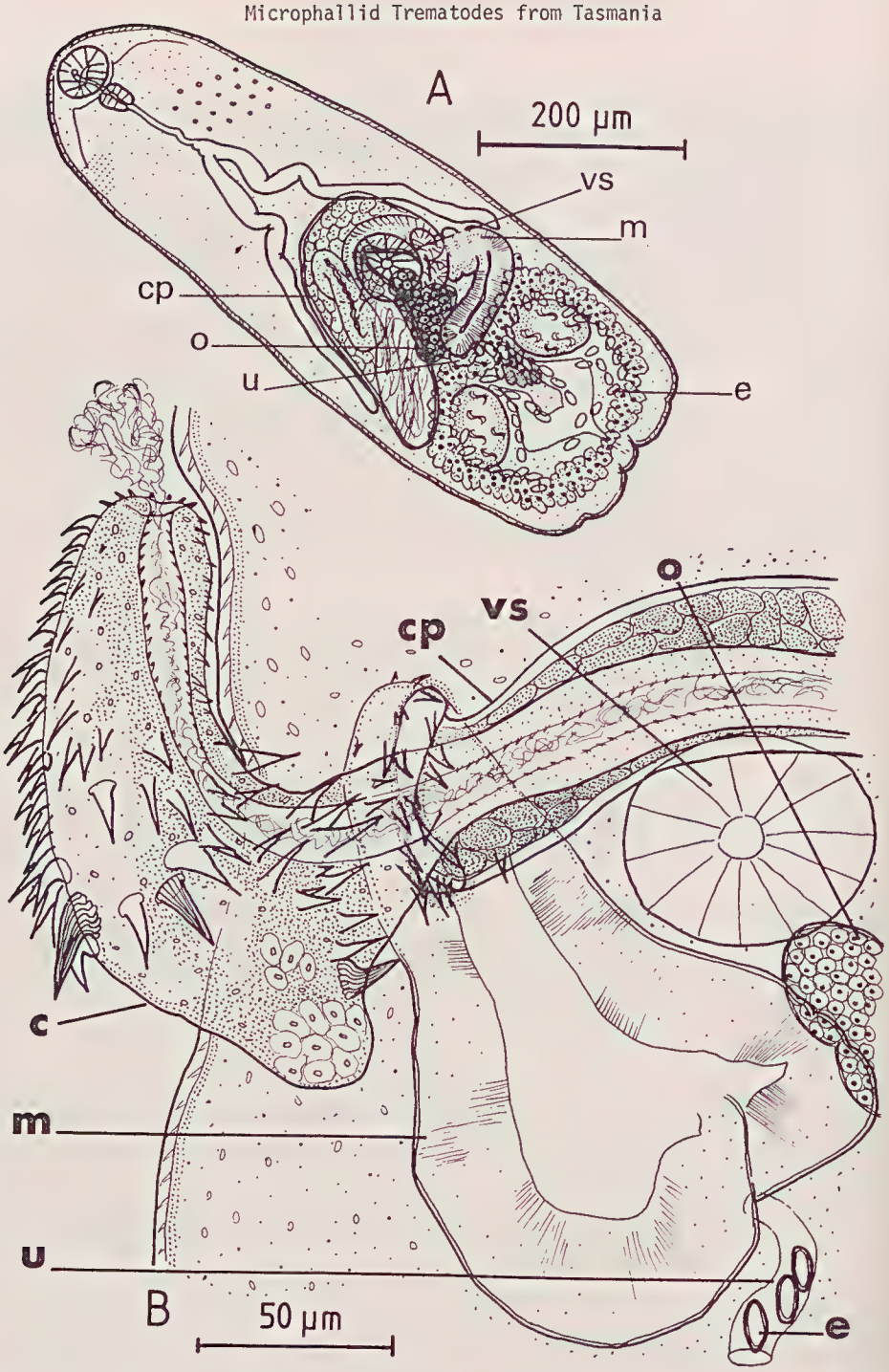

FIG. 4 - *Maritrema eroliae*. A: gravid adult, ventral view; B: flattened gravid adult, detail of everted cirrus, dorsal view. (c: cirrus, cp: cirrus pouch, e: egg, m: metraterm, o: ovary, vs: ventral sucker, u: uterus).

inal vitelline reservoir. Flame-cell formula not determined. Excretory vesicle Y-shaped, arms extending to anterior margins of testes.

Experimental definitive host
Anas platyrhynchos Linnaeus.

Crustacean intermediate host
Paragrapsus gaimardii (M. Edw.).

Geographical location
Great Bay, Bruny Island, Tasmania.

Site of encystment
Body cavity.

Material
Tasmanian Museum and Art Gallery - K892 gravid adult (flattened, cirrus everted); K893 gravid adults; K894 non-ovigerous, excysted metacercariae.

TABLE 4

EXCYSTED METACERCARIAE OF *MARITREMA EROLIAE*.
Dimensions of metacercariae excysted *in vitro*, after about 3 hours at 41°C. All metacercariae relatively mature, with active vitellaria (n = 15).

Body:length (BL)	683 (620-794)
width	258 (217-293)
Oral sucker:length (OS)	47 (40-53)
width	51 (46-57)
Prepharynx length	40 (30-53)
Oesophagus length	86 (65-133)
Pharynx:length	28 (23-30)
width	24 (21-27)
Left caecum length	292 (251-342)
Right caecum length	307 (274-357)
Ventral sucker:length (VS)	64 (61-70)
width	61 (57-67)
Cirrus pouch:length (CPL)	350 (323-380)
width	82 (68-91)
Seminal vesicle:length	141 (114-156)
width	59 (49-68)
Metraterm:length	117 (103-137)
width	62 (46-80)
Ovary:length	108 (87-125)
width	59 (46-76)
Left testis:length	71 (65-76)
width	52 (42-57)
Right testis:length	76 (65-87)
width	53 (46-61)
Roundness (BL/BW)	2.65
OS (l+w)/ VS (l+w)	0.78
CPL/BL	0.51

2. Metacercarial cyst (fig. 2)

The cyst is oval and quite large. Dimensions are presented in table 5. The cyst wall is composed of a clear uniform inner layer about 10 µ thick, overlain by a darker layer about 12 µ thick, traversed by fine radial striations or fissures. A thin outer membrane, about 1 µ wide, envelops the whole cyst. The cyst occurs free, or lightly bound by connective tissue, within the body cavity of *Paragrapsus gaimardii*.

Encysted metacercariae reach an advanced state of sexual development. Although they excyst at varying degrees af maturity, more advanced specimens have phenolic egg-shell precursors in the vitellaria, and commence egg production within a few hours at 41°C, in Hank's BSS and in Eagle's MEM.

TABLE 5

CYSTS OF *MARITREMA EROLIAE*.
Dimensions of live metacercarial cysts,
dissected from *Paragrapsus gaimardii*, (n=20).

External diameter	length	458 (423-484)
	width	304 (289-331)
Internal diameter	length	402 (370-423)
	width	254 (239-274)

3. Relationships

The anatomy of this microphallid, with very large cirrus pouch, spiny cirrus, vast metraterm and median ovary, is characteristic of a distinctive and homogeneous group of *Maritrema* species: *M. eroliae* Yamaguti, 1939, *M. echinocirrata* Leonov, 1958, *M. patulus* Coil, 1955, and *M. misenensis* (Palombi, 1940) Prevot, Bartoli and Deblock, 1976. The evaginated cirrus of the latter species is free of spines, except for a zone around the base, mainly proximal to a distinct "heel". *M. patulus* is morphologically identical to *M. eroliae*, and Prevot *et al.*, 1976, consider that when its life-cycle is discovered it may fall into synonymy with *M. eroliae*. *M. echinocirrata* differs from *M. eroliae* only in the absence of the large thorn-like spines at the base of the evaginated cirrus. The Tasmanian flukes fall within the range of variation described for *M. eroliae* by Deblock (1975).

The metacercariae of *M. eroliae* has previously been found encysting in various decapod crustaceans in Japan (Ogata 1951, Shibue 1953, and Bridgman *et al.* 1972). The oval cyst varies greatly in size and thickness, possibly in relation to the identity of the second intermediate host. The cysts found in Tasmanian crabs are intermediate in size between those infecting *Macrophthalmus dilatatus* , 520-690 × 360-450 µ (Ogata 1951; and Bridgman *et al.* 1972), and those infecting *Neocaridina denticulata*, 280-320 × 240-270 µ (Shibue 1953), and *Scopimer* spp., 310-360 × 210-240 µ (Ogata 1951). The adult of *M. eroliae* has been found only in birds inhabiting the eastern border of the Pacific Ocean (Deblock 1975); and in Australia, has been recorded in the Mongolian dotterel, *Charadrius mongolus* Pallas, in Queensland (Deblock & Pearson 1968b).

MICROPHALLUS PARAGRAPSI N.SP.

1. Adult

The adult, illustrated in fig. 5, is described below from ovigerous specimens cultured *in vitro* and non-ovigerous specimens taken from a laboratory duckling. Dimensions of unflattened, ovigerous specimens are not available, however gravid adults appear to be the same size as relatively mature excysted metacercariae (with phenolic egg-shell precursors in the vitellaria), dimensions of which are included in table 6b. Dimensions of very immature excysted metacercariae are shown in the same table. Non-ovigerous adults (some with phenolic egg-shell precursors), recovered from an experimentally infected duckling, were intermediate in size between immature and mature excysted metacercariae (table 7).

Description

Body varies from pyriform to elongate spatulate, frequently with distinct waist just anterior to seminal vesicle, causing dumb-bell appearance. Lateral body margins of worms cultured *in vitro* generally folded ventrally. Tegumental spines quincuncially

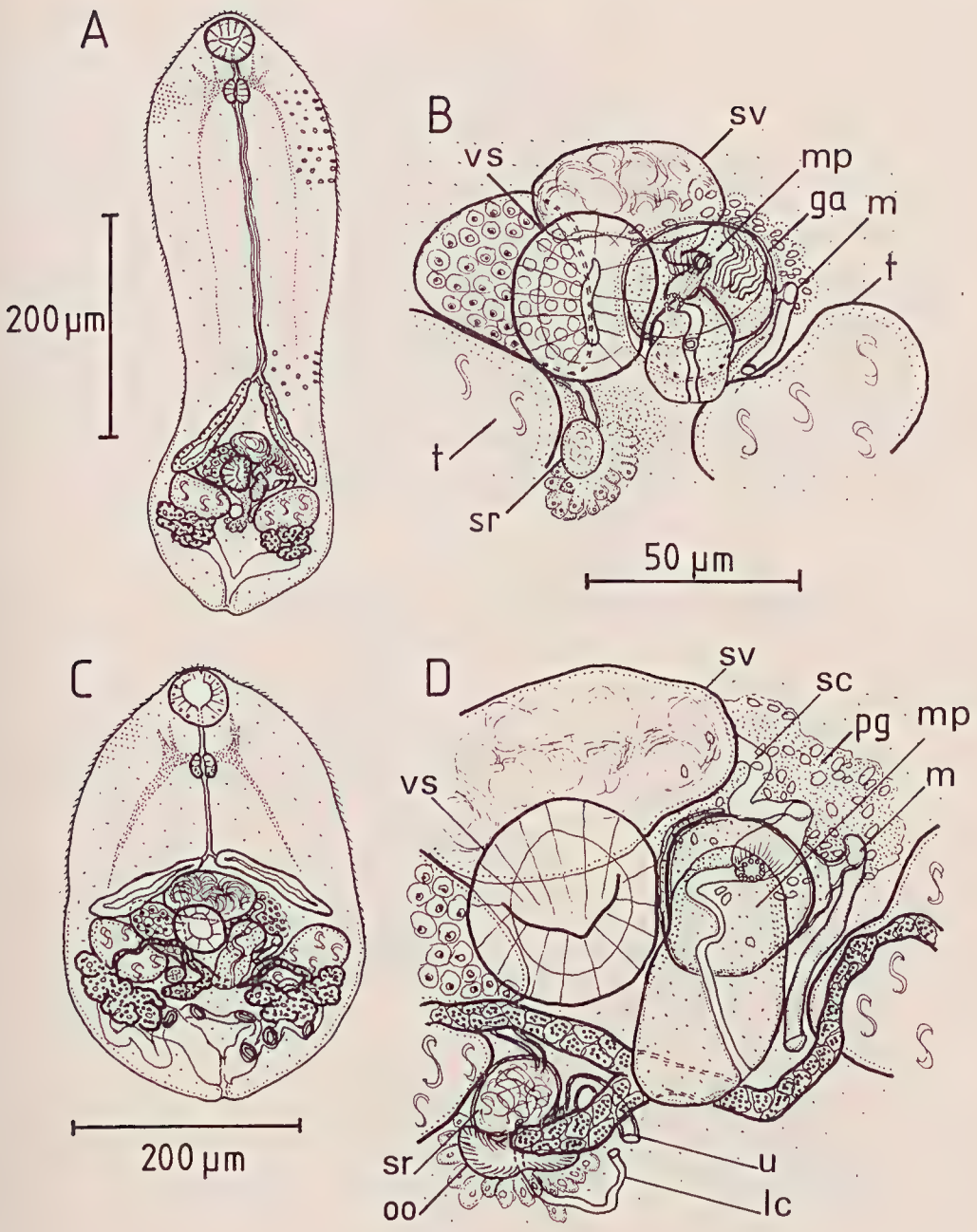

FIG. 5 - *Microphallus paragrapsi* n.sp. A: holotype, after 17 hours in laboratory duckling, ventral view; B: detail of ventral sucker region of holotype; C: flattened gravid adult, cultured *in vitro* at 41°C for 2 days, ventral view; D: detail of ventral sucker region of adult shown in C. (ga: genital atrium, lc: Laurer's canal, m: metraterm, mp: male papilla, oo: ootype, pg: prostate gland, sc: seminal canal, sr: seminal receptacle, sv: seminal vesicle, t: testis, u: uterus, vs: ventral sucker).

arranged, diminishing in size posteriorly, extending to waist level. Tegumental gland cells distributed over anterior body. Oral sucker transversely oval to round, mouth subterminal ventral. Prepharynx short, about 1/20th length of oesophagus. Oesophageal bifurcation in posterior half of body. Caeca relatively short, terminating at midlevel of ventral sucker. Ventral sucker round, smaller than oral sucker. Testes oval, equal, posterolateral. No cirrus pouch; seminal vesicle oval, partly dorsal to ventral sucker. Seminal canal short, leading posteriorly from seminal vesicle to expanded pars prostatica, about 6 μ diameter, at base of male papilla. Prostate gland cells located between seminal vesicle and male papilla, clustered around seminal canal; secreting through undetermined number of small ducts, into pars prostatica. Retracted male papilla coiled or folded within genital atrium, measures 34(30-38) × 29(27-30) μ. Everted male papilla, tubular, not lobed, directed posteromedially; length 66(53-76) μ, width at base 26(23-30) μ, width at tip 22(19-25) μ. Ejaculatory canal, about 4 μ diameter, mainly axial within male papilla, but opens eccentrically. Ovary oval, contiguous to dextral caecum and testis, dextral and partly dorsal to ventral sucker. Oviduct passes posteromedially to bulbous seminal receptacle, from which Laurer's duct leads to dorsal surface. Ootype located between testes, posterior to ventral sucker. Uterus forms post-testicular loops, overlapping each testis. Metraterm enters left side of genital atrium. Vitelline gland cells clustered in compact bunches posterior to each testis. Vitelline ducts pass anteromediad, joining to form longitudinal vitelline reservoir, posterior to ventral sucker. Oval eggs, numerous, 19(17-21) × 10(8-13) μ, (fixed, flattened). Flame-cell formula not determined. Excretory vesicle V-shaped, limbs extending to testes.

TABLE 6

EXCYSTED METACERCARIAE OF *MICROPHALLUS PARAGRAPSI* N.SP.
Dimensions of metacercariae excysted *in vitro*, after about 3 hours at 41°C: (a) smaller, less mature specimens; (b) larger, more mature specimens, some with active vitellaria.

	(a) n = 20	(b) n = 20
Body:length (BL)	355 (287-469)	579 (484-665)
width (BW)	156 (137-117)	184 (156-209)
Oral sucker:length (OS)	38 (34-40)	40 (34-46)
width	40 (36-42)	44 (42-49)
Prepharynx length	4 (4-49)	12 (4-27)
Oesophagus length	115 (87-114)	275 (220-319)
Pharynx: length	22 (17-23)	25 (19-27)
width	18 (17-19)	21 (19-25)
Left caecum length	88 (76-99)	128 (110-156)
Right caecum length	87 (72-99)	126 (103-137)
Ventral sucker:length (VS)	35 (30-38)	40 (34-46)
width	31 (23-36)	40 (34-44)
Seminal vesicle:length	-	39 (34-42)
width	-	27 (23-36)
Ovary:length	31 (23-34)	41 (38-46)
width	25 (17-30)	34 (30-38)
Left testis:length	45 (34-53)	59 (57-61)
width	38 (29-46)	51 (38-57)
Right testis:length	50 (34-61)	61 (53-68)
width	35 (27-42)	46 (42-51)
BL/BW	2.28	3.15
OS (l+w)/VS (l+w)	1.18	1.05

Experimental definitive host
Anas platyrhynchos Linnaeus

Crustacean intermediate host
Paragrapsus gaimardii (M.Edw.)

Geographical location
Great Bay, Bruny Island, Tasmania

Site of encystment
Nerves of legs and claws

Type material
Tasmanian Museum and Art Gallery - K903 holotype, non-ovigerous adult (ringed); K903 paratypes, non-ovigerous adults (not ringed); K904 paratypes, ovigerous adults (ringed, flattened); K905 and K906 paratypes, excysted metacercariae.

TABLE 7

NON-OVIGEROUS ADULTS OF *MICROPHALLUS PARAGRAPSI* N.SP.
Dimensions of the holotype (a), and other non-ovigerous adults (b), from an experimentally infected duckling 17 hours after infection.

	(a) n=1	(b) n=9
Body:length (BL)	544	460 (325-544)
width (BW)	171	159 (137-179)
Oral sucker:length (OS)	42	38 (34-40)
width	44	41 (36-44)
Prepharynx length	11	14 (8-23)
Oesophagus length	243	199 (110-258)
Pharynx:length	27	22 (19-25)
width	19	19 (17-23)
Left caecum length	114	95 (72-110)
Right caecum length	114	98 (80-110)
Ventral sucker:length (VS)	40	39 (34-42)
width	34	34 (30-38)
Ovary:length	38	40 (36-46)
width	34	34 (27-38)
Left testis:length	57	55 (46-65)
width	38	40 (30-46)
Right testis:length	55	54 (46-61)
width	46	46 (38-49)
BL/BW	3.18	2.89
OS (l+w)/VS (l+w)	1.16	1.08

2. Metacercarial cyst (fig. 2)

The cyst is round, colourless, and quite thick-walled. Its dimensions are shown in table 8. The uniformly thick cyst wall, about 36(27-44) µ wide, is composed of two layers: a clear, homogeneous inner layer, 14(10-19) µ, and a darker, outer layer with fine radial striae, 22(17-27) µ. The cyst occurs within the large nerves innervating the legs and claw muscles of the crab host, particularly near the coxae. No behavioural changes related to this infection have been noticed in the crab host.

Great variation was recorded in the time required by metacercariae for excystment at 41°C. The time was directly related to the size and maturity of excysted metacercariae: smaller, less mature metacercariae, possibly with incompletely formed cyst walls, excysted sooner than larger more mature specimens (table 9). Advanced metacercariae have phenolic

egg-shell precursors in the vitellaria, and produce eggs *in vitro* after 2 days at 41°C, in Eagle's MEM plus 20% foetal calf serum.

TABLE 8

CYSTS OF *MICROPHALLUS PARAGRAPSI* N.SP.
Dimensions of live metacercarial cysts,
dissected from *Paragrapsus gaimardii*, (n=20).

External diameter	length	319 (300-353)
	width	310 (285-331)
Internal diameter	length	246 (228-266)
	width	239 (224-251)

TABLE 9

SIZE VARIATION IN EXCYSTED METACERCARIAE OF *MICROPHALLUS PARAGRAPSI* N.SP.
Size of metacercariae excysted *in vitro* at 41°C: (a) after 1½ hours; and
(b) from 1½ to 12 hours.

	(a) n=20	(b) n=20
length	351 (249-507)	479 (333-665)
width	154 (125-175)	185 (144-213)

3. Relationships

The species of *Microphallus* encysting in the nerves of the crab *Paragrapsus gaimardii* in Tasmania is considered to be new, and is named after its second intermediate host. Only one other microphallid species is known to encyst in the nerves of the limbs of its crustacean host: *Microphallus pachygrapsi* Deblock & Prevot, 1968, encysts in the crab *Pachygrapsus marmoratus* on the Mediterranean coast of France. *Microphallus paragrapsi* n.sp. and *M. pachygrapsi* adults are similar in size, but differ in the following respects: the former has OS:VS greater than 1, and male papilla length greater than VS diameter; the latter has OS:VS less than 1, and male papilla length less than VS diameter. Metacercarial cysts of *M. paragrapsi* n.sp. are round whereas those of *M. pachygrapsi* are oval. According to the key to species of *Microphallus* presented by Deblock (1971), the species most similar to *M. paragrapsi* n.sp. is *M. minutus*, a tiny fluke discovered in water rats captured on the banks of the Murray River at Tailem Bend, South Australia (Johnston 1948) and rediscovered and redescribed by Deblock (Pearson (1969), in the same host, captured near Brisbane, Queensland. The adults of *M. paragrapsi* n.sp. and *M. minutus* are very similar, however the average size of gravid *M. minutus* adults, 290 × 160 µ (Deblock & Pearson 1969), is slightly less than the average size of the more immature excysted metacercariae of *M. paragrapsi* n.sp., 355 × 156 µ, and markedly less than the average size of mature excysted metacercariae of *M. paragrapsi* n.sp., 579 × 184 µ. The male papilla of *M. minutus*. 53 × 27 µ, is less elongate than that of *M. paragrapsi* n.sp., 66 × 26 µ. In relation to body size, the oral and ventral suckers of *M. minutus* are much larger than those of *M. paragrapsi* n.sp. On the basis of these differences, and in the absence of further life-history information, *M. paragrapsi* n.sp. and *M. minutus* are considered to be distinct, but closely related species. Four other species of *Microphallus* has been recorded in Australia (Deblock & Pearson 1969), however, all are readily distinguished from *M. paragrapsi* n.sp. by details of the reproductive system: *M. minutus* has a large, robust male papilla of the "papillorobustus" type; *M. papillornatus* has an ornamented male papilla; *M. vaginosus* has an unusual, large metraterm, with thick folded walls; and *Microphallus* sp. has a voluminous ovoid papilla, about the same width as the ventral sucker.

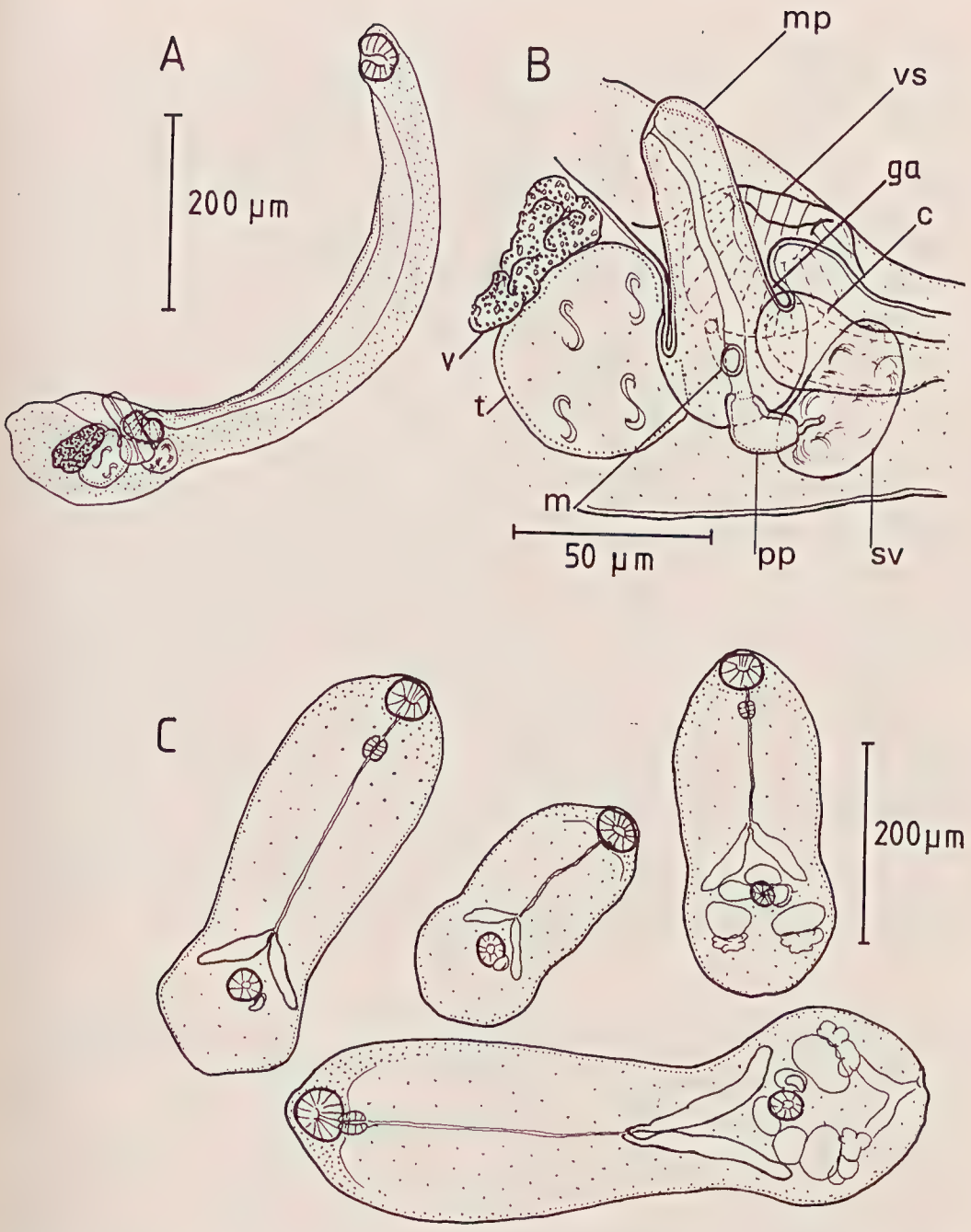

FIG. 6 - *Microphallus paragrapsi* n.sp. A: excysted metacercaria, after 12 hours at 41°C, lateral view; B: detail of everted male papilla of metacercaria shown in A; C: variation in form and size of excysted metacercariae, after 12 hours at 41°C. (c: caecum, ga: genital atrium, m: metraterm, mp: male papilla, pp: pars prostatica, sv: seminal vesicle, t: testis, v: vitellaria, vs: ventral sucker).

DISCUSSION

The incidence of infection of *Paragrapsus gaimardii* with microphallid trematodes has not been determined, however the impression gained from dissection of many crabs from Great Bay, at irregular intervals over several years, is that almost all adult crabs, of both sexes, are infected by *Gynaecotyla* spp., *Maritrema eroliae*, and *Microphallus paragrapsi* n.sp., throughout the year. Two large male crabs dissected in July 1977 were infected by an average of 197(118-275) metacercarial cysts of *Gynaecotyla* spp., 195(90-300) of *M. paragrapsi* n.sp., and 14(2-26) of *Maritrema eroliae*. These crabs also contained an average of 19(15-23) large, unencysted immature metacercariae of *Gynaecotyla* spp. These specimens had an oral sucker, a large excretory bladder, and some individuals also had ventral suckers and rudimentary digestive and reproductive systems. Delayed encystment is known in the life-cycles of a number of *Gynaecotyla* species, and in *G. adunca* and *G. longiintestinata*, a small percentage of metacercariae mature and produce eggs, without encysting (Deblock 1977). The cysts of the two *Gynaecotyla* species infecting *P. gaimardii* have not been distinguished, however, the ratio of the two species in 100 metacercariae, excysted *in vitro* from cysts dissected in December 1979, was about 6 *G. hickmani* n.sp. to 1 *G. macrocotylata* n.sp. The molluscan hosts of these four microphallid species are as yet unknown. The Mongolian dotterel, which harbours *Maritrema eroliae* in Queensland, is an infrequent visitor to Tasmanian shores, and might have introduced this trematode to the fauna of Great Bay. An estuarine fish, the leatherjacket, caught in the Derwent River, was found by Last (1975) to harbour a single microphallid in its intestine, which appears to be an immature adult of *Maritrema eroliae*. As experimental evidence indicates that a temperature of about 40°C is required for oviproduction in *M. eroliae*, eggs are unlikely to be produced in this host. Attempts to experimentally infect eight domestic ducklings with hundreds of cysts of these four Tasmanian microphallids were not very successful. No ducklings were infected by the two *Gynaecotyla* species; three ducklings, dissected 17, 18 and 26 hours after being fed with cysts, were infected with 16, 1 and 1 immature adults of *Microphallus paragrapsi* n.sp. respectively; and one duckling dissected after 17 hours was infected by one gravid adult of *Maritrema eroliae* that contained 52 uterine eggs.

The discovery and identification of four microphallid species concurrently infecting a single species of crab in Tasmania presents many challenging problems. The site of encystment of *Microphallus paragrapsi* n.sp. is unusual, and presumably of selective value to the parasite. This trematode may increase its chances of transmission by making its intermediate host more vulnerable to predation. An investigation of the effect of *M. paragrapsi* n.sp. cysts on the function of the nerves and the behaviour of *Paragrapsus gaimardii*, may help to explain why two microphallids, *M. paragrapsi* n.sp. in Tasmania and *M. pachygrapsi* in France, invade the nerves of their crustacean hosts. The life history of none of the four microphallids infecting *P. gaimardii* is known. Elucidation of their life-cycles at Great Bay will facilitate discovery of their life-cycles at other locations in Australia, and the life-cycle of *Maritrema eroliae* in Japan.

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BIRDS IN TASMANIAN PINE PLANTATIONS

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(with two tables)

ABSTRACT

WALL, L.E., 1983 (31 viii): Birds in Tasmanian pine plantations. *Pap. Proc. R. Soc. Tasm.*, 117: 125-133. ISSN 0080-4703. 63 Elphinstone Road, North Hobart, Tasmania.

The number of bird species in *Pinus radiata* plantations aged between 8 and 31 years and in native forests in Tasmania during a year is recorded.

The oldest plantations had a slightly greater number of species than the younger ones because after thinning of the pines there was some regeneration of ground cover which provided another habitat. Most species, however, fed chiefly on the trunks and foliage of the pines. The number of species was greater in the native forests and was consistent in the five plots surveyed. Only one species was found nesting in the pine plots.

INTRODUCTION

Exotic pines, principally Monterey pines, have been cultivated as a source of millable timber and for pulpwood in Australia in increasing numbers during the last forty years. During this time there has been growing concern that these plantations have been replacing native forests to the detriment of the native fauna and flora.

Several studies have been undertaken in other Australian States to ascertain the extent of this problem, e.g. Pawsey (1966), d'Andria (1968), Cowley (1971), Kloeden (1973), Gepp & Fife (1975), Suckling *et al.* (1976), Davidson (1976), Disney & Stokes (1976), Gepp (1976), Driscoll (1977), and Friend (1982), and one brief study in Tasmania by Fielding (1976). In most of these the study plots were many hectares in area and contained watercourses, firebreaks and native vegetation so that the results might not be truly representative of bird populations in pure pine plantations.

My study was undertaken to assess the numbers of bird species in pine plantations not affected by other influences, and to compare these with the birdlife in adjacent native forests.

METHODS

Six plots in Monterey pine plantations and five study plots in adjacent native forests were selected for study. Five of the pine plots were 200 m^2 (4 ha in area) and the sixth was a triangular plot 4.9 ha in area. In all plots the canopy was closed but the ages of the trees varied from 8 to 31 years, and the amount of thinning and pruning varied also. To overcome any local bias three plots of different ages were chosen in the Burnie district of northwestern Tasmania and three plots of approximately the same ages in the Scottsdale district in northeastern Tasmania.

Whenever feasible, observations in each plot were alternated between morning and afternoon. Plots were chosen free from native vegetation wherever possible, and creeks, roadsides and other influences excluded. Each observation plot was a small part of a much larger plantation. Further details about each plot are given below.

Monthly visits were made to each plot and one hour spent in recording all birds seen or heard. Another period of observations, not exceeding one hour, was spent in nearby native forest. By extending the study for a full year, from August 1981 to July 1982, any seasonal fluctuations were recorded. The usual routine for each visit was to traverse the boundaries of the plot and then to criss-cross it at random.

Common names of birds are those recommended in "The Emu", vol.77 supplement, May 1978. For ferns I have used the common names from N.A. Wakefield's "Ferns of Victoria and Tasmania", 1955; for fungi I have used the common names from Macdonald & Westerman's "A Field Guide to Fungi of South-eastern Australia", 1979; and for other plants I have followed "The Student's Flora of Tasmania" by W.M. Curtis, 1956-1967.

PLOT DESCRIPTIONS

1. Kamona, near Scottsdale (part of Forestry Commission Compartment 4)
Planted 1950, at spacing 2.4 × 2.4 m (i.e. 8 × 8 feet)

1st pruning	1957-8 to 2 m	1st thinning	1965-8
2nd pruning	1958-9 to 4.3 m	2nd thinning	1974-5
3rd pruning	1959-60 to 6.4 m	3rd thinning	1979-81

On a gentle slope facing west; altitude about 100 m.
Soil - yellow podzols on granite.

As a result of thinning there is a good penetration of sunlight on this plot resulting in about 80% ground cover of austral king-fern, austral bracken and other ground ferns, with scattered dogwood, fireweed, native currant and seedling pines up to 2 m high. In the autumn there is substantial growth of the introduced fly agaric.

The wet sclerophyll forest used as a control is immediately west of Compartment 4. It is dominated by swamp gum, and blackwood with dogwood understorey and ground cover of austral bracken and other ferns.

2. Cuckoo, near Scottsdale (part of Forestry Commission Compartment 9)
Planted 1954, at spacing 2.4 × 2.4 m.

Pruned	1962-63	1st thinned	1977-78

On a steep slope facing south; altitude about 250 m.
Soil - yellow podzols on granite.

The ground cover is very sparse - occasional soft treeferns and very few austral bracken stems. Fly agaric is very common in autumn.

The wet sclerophyll rainforest used as a control is nearby on the east side, with a creek running through it. It is dominated by swamp gum, blackwood and myrtle with understorey of dogwood and musk and ground cover of ferns.

3. Cuckoo, near Scottsdale (part of Forestry Commission Compartment 37)
Planted 1966, at spacing 2.7 × 2.7 m.
Unthinned and unpruned.
On a medium slope facing north; altitude about 200 m.
Soil - yellow podzols on granite.

There is extensive die-back of needles on lower branches. A few dogwoods occur in the lower section of the plot. A gravel road runs diagonally through this plot but there is no roadside vegetation and the canopy remains closed.

A wet sclerophyll forest on the southeastern side is used as a control. It is dominated by swamp gum and stringybark, blackwood and silver wattle, with an understorey of dogwood and musk and a ground cover of ferns.

4. Oldina, near Burnie (part of Forestry Commission Compartment 54A)
Planted 1952, at spacing 2.4 × 2.4 m.
1st pruning to 2.4 m 1959 Thinned 1968-69
2nd pruning to 4.9 m 1960
3rd pruning to 6.7 m 1962
On a gentle slope facing west, altitude about 80 m.
Soil - clay of basaltic origin.

A sparse ground cover of mother shield-fern, austral bracken, saggs and low blackberry vines. In autumn there are considerable amounts of fungi, principally fly agaric and saffron milk cap.

A wet sclerophyll/rainforest around a small grassed picnic ground 2 km south was used as a control. A small creek flows through it. It is dominated by stringybark and manna gum, blackwood and a few myrtles. The understorey is composed of silver wattle and cheesewood, with ground cover of austral bracken, other ferns and blackberries (very profusely).

5. East Ridgley, near Burnie (part of Associated Forest Holdings plantation)
Planted 1969 at spacing 3 × 2 m.
Thinned by removing each third row in 1981; unpruned.
Soil - clay of basaltic origin; altitude about 250 m.

A triangular plot, very steep in part but mostly gently sloping to the west.

There was some wind damage because this plot takes the full force of the prevailing winds. Much trash from the thinning operations remains on the ground. There was a strong growth of grass and thistles where rows of trees had been removed, and very few austral bracken stems and fireweed. In the autumn a moderate number of fungi, mostly fly agaric, was in evidence.

In February, cattle from the neighbouring farm were feeding on the grass but not on the thistles. In March, the cattle had been removed and the thistles were seeding heavily, but there was no indication that they were attracting birds.

This plantation is surrounded by grazing lands with no native forests in the vicinity to be used as a control. The plantation was chosen because the thinning differs from Forestry Commission practice but there is no evidence that the different practices have any effect on the birdlife.

6. West Ridgley, near Burnie (part of Associated Forest Holdings plantation)
Planted 1973, with spacing 3 × 2 m.
Unthinned and unpruned; extensive needle dieback on lower branches.
A level plot except for a slight fall near the western boundary.
Soil - clay of basaltic origin; altitude about 260 m.

A road skirts the eastern boundary with blackberries on the verge. A small depression within the plot is encircled by blackberries and sometimes contains water, and near the western boundary are a few straggling dogwoods and silver wattle saplings.

Just to the east of this plot is a similar area of wet sclerophyll forest used as a control. It is dominated by stringybark and blackwood, with an understorey of cheesewood and mountain pepper and a ground cover of blackberries, austral bracken and other ferns.

RESULTS

In Plot 1 six species were seen on at least five visits: ranked in order of number of visits on which each was sighted they were - grey shrike-thrush (12), Tasmanian thornbill (11), green rosella (10), superb fairy-wren (10), white-browed scrubwren (9), dusky robin (6).

In contrast, nine species were seen on at least five visits to the native forest: ranked in order of the number of visits on which each was seen these were - grey fantail (11), green rosella (11), forest raven (10), Tasmanian thornbill (10), grey shrike-thrush (8), blackbird (7), pink robin (6), laughing kookaburra (5), grey currawong (5).

A total of 28 species was recorded in native forest and 18 in pines.

In Plot 2 only one species, grey shrike-thrush, was recorded on at least five visits to the pines; it was seen on eight visits. On three visits no birds were seen.

In the native forest eight species were seen on at least five visits: ranked in order of the number of visits on which each was seen these were - grey shrike-thrush (11), Tasmanian thornbill (11), grey fantail (9), golden whistler (7), silvereye (7), green rosella (6), white-browed scrubwren (6), forest raven (5).

A total of 22 species was recorded in native forest and 12 in pines.

In Plot 3 only two species - Tasmanian thornbill (8) and White's thrush (5) - were recorded on at least five visits to the pines.

In the native forest 12 species were recorded on at least five visits: in order of the number of visits on which each was seen they were - grey shrike-thrush (10), grey fantail (10), Tasmanian thornbill (9), white-browed scrubwren (9), green rosella (8), blackbird (7), superb fairy-wren (7), forest raven (7), strong-billed honeyeater (6), golden whistler (5), eastern spinebill (5), silvereye (5).

A total of 26 species were recorded in native forest and 14 in pines.

In Plot 4 five species were recorded on at least five visits to the pines: in order of the number of visits on which each was seen they were - forest raven (7), grey shrike-thrush (7), blackbird (6), Tasmanian thornbill (6), dusky robin (5). In the native forest seven species were recorded on at least five of ten visits: in order of the number of visits on which each was seen they were - Tasmanian thornbill (9), golden whistler (8), grey shrike-thrush (8), grey fantail (8), superb fairy-wren (8), green rosella (7), forest raven (6).

A total of 27 species was recorded in native forest and 14 in pines.

In Plot 5 three species were recorded on five or more visits: in order of number of visits on which each was seen they were - grey shrike-thrush (9), Tasmanian thornbill (7), green rosella (5).

As indicated earlier there was no native forest adjacent to this plot for comparative purposes.

A total of 14 species was recorded in this plot.

In Plot 6 only one species, Tasmanian thornbill (7), was recorded on at least five visits.

Eight species were recorded in the native forest on at least five visits: in order of the number of visits on which each was seen they were - grey fantail (10), Tasmanian

thornbill (10), blackbird (9), superb fairy-wren (9), green rosella (8), grey shrike-thrush (8), forest raven (8), white-browed scrubwren (7).

A total of 24 species was recorded in native forest and 11 species in pines.

Table 1 summarises the sightings in all plots.

TABLE 1

COMPARISON OF THE NUMBER OF BIRD SPECIES
recorded in pine plots and native forests (bracketed numbers) in Tasmania.
Number of visits on which each species was recorded.

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Brown goshawk						(1)
Peregrine falcon				(1)		
Brown falcon			(1)			(1)
Swamp quail				(1)		
Tasmanian native-hen	(1)			(2)		
Brush bronzewing	(4)	(1)	1	(3)		(1)
Yellow-tailed black-cockatoo		(2)	(1)			
Green rosella	10 (11)	3 (6)	3 (8)	3 (7)	5	2 (8)
Fan-tailed cuckoo	4 (4)	(2)	(2)	1 (2)	1	(1)
Shining bronze-cuckoo	(1)	(2)	(1)	(2)		
Laughing kookaburra	2 (5)		1 (1)	1		
Welcome swallow				(4)		
Black-faced cuckoo-shrike	(2)				1	
White's thrush	(3)	3	5 (1)	1 (2)	1	1
Blackbird	4 (7)	1 (4)	4 (7)	6 (3)	4	4 (9)
Pink robin	2 (6)	1 (4)	2 (1)	(2)	1	
Flame robin		1		1 (1)		(1)
Scarlet robin	2 (3)	2	2 (1)	1	2	
Dusky robin	6 (2)	1		5 (3)	1	(2)
Olive whistler	3 (4)	(2)	2 (1)			(2)
Golden whistler	(3)	(7)	(5)	(8)		(2)
Grey shrike-thrush	12 (8)	8 (11)	3 (10)	7 (8)	9	4 (8)
Satin flycatcher				(1)		
Grey fantail	4 (11)	(9)	2 (10)	1 (8)	1	2 (10)
Superb fairy-wren	10 (3)	(2)	(7)	3 (8)	4	1 (9)
White-browed scrubwren	9 (3)	(6)	1 (9)	(2)		3 (7)
Scrubtit	2	(1)				3
Brown thornbill	4					(1)
Tasmanian thornbill	11 (10)	4 (11)	8 (9)	6 (9)	7	7 (10)
Yellow-throated honeyeater	(2)	(3)	(3)	(4)		(3)
Strong-billed honeyeater	(1)		(6)			(3)
Black-headed honeyeater			(1)			
Crescent honeyeater	(1)			(3)		
Eastern spinebill	(2)	(2)	(5)			1
Striated pardalote	(4)	(2)	(1)	(2)		(3)
Silvereye	3 (4)	(7)	3 (5)	(4)		1 (3)
European goldfinch				1 (2)	2	(3)
Beautiful firetail				(1)		(2)
Common starling						(2)
Grey butcherbird	(2)					
Black currawong		1 (2)	(2)			
Grey currawong	1 (5)	1 (2)	(3)			
Forest raven	2 (10)	2 (5)	1 (7)	7 (6)	4	(8)
Total species recorded	18 (28)	12 (22)	14 (26)	14 (27)	14	11 (24)

DISCUSSION

Pawsey (1966) compared the bird populations of pine forests in southeastern South Australia in 1950 and 1965 and concluded that the number of species in closed canopy forests, including firebreaks, had increased almost fivefold in that period. He presumed that increased insect life had caused the increase. It is not possible to relate this to my observations because Pawsey gave insufficient data on tree spacing and his study plots included firebreaks and clearings of unknown extent. Further, there had been no thinning of the pines before 1950 and the extent of subsequent thinning, which could have allowed extensive growth of ground cover, is unknown to me.

Thirteen species were recorded in a very brief survey of Majura forest pine plantation, aged forty years, near Canberra, by d'Andria (1968), but these results are not comparable with mine because in the Canberra plot there was no undergrowth and the spacing of trees and the extent of thinning was not stated. Davidson (1976) referred to this forest and stated that some had been pruned and thinned and there were a few creeks but this does not specifically refer to the same part as that surveyed by d'Andria.

Cowley (1971) gave a summary of the relationship between birds and forests. He referred to a survey undertaken in pine plantations in Creswick, Victoria, but this was restricted to mature pines and the extent of thinning and presence of native undergrowth was not shown so that a comparison with my study must be imprecise. Cowley showed that the number of bird species in pines was only 52% of those in eucalypt forest (whether wet or dry sclerophyll was not stated) and this accords with my results in Tasmania.

In 1972 at Silver Creek, Victoria, Kloeden (1973) reported that 47 species were observed in native forest and 42 species in pine plots, and at Longford, Victoria, 52 species in native forests and 37 species in pine plots. These results do not provide a satisfactory comparison because although the pine plots were of varying ages the results were combined and the extent of thinnings, if any, were not given.

Gepp & Fife (1975) recorded the number of bird species in pine plantations of varying age and structure and in native forest in South Australia in 1974. The age and extent of thinning in these pine plots seemed similar to those in my study plots. Comparative results are shown in table 2. They indicate that each of the South Australian plots had many more species than those in Tasmania but this is predictable because Tasmania has a paucity of species (Ridpath & Moreau 1966). In South Australia and in Tasmania the native forests had more than double the numbers of birds species present than were present in pine forests, but the proportions of the species seen frequently in all the South Australian pine plots were greater than in Tasmania. However, the native forests in Tasmania had a greater proportion of species seen frequently than in South Australia.

TABLE 2

COMPARISON OF THE NUMBER OF BIRD SPECIES
recorded in pine plots and native forest
in South Australia and Tasmania.

	Total number of species		Number of frequently seen species		Percentage of frequently seen species	
	S.A.	Tasm.	S.A.	Tasm.	S.A.	Tasm.
Unthinned	32	17	17	2	53	12
Middle-aged (thinned)	35	18	18	4	51	22
Old	39	13	18	4	49	31
Native forest	78	43	15	15	19	35

There do not appear to be clear reasons for these differences. It should be noted that the South Australian survey was in dry sclerophyll forest whereas my study was in wet sclerophyll. Disney & Stokes (1976) stated that wet sclerophyll forests in New South Wales contained a greater diversity of bird species than dry sclerophyll forests but this does not apply in Tasmania (Ratkowsky & Ratkowsky 1978, 1980).

A survey in northeastern Victoria in pine plantations of varying ages and in mature eucalypt forest was carried out by Suckling *et al.* (1976). This is not comparable with my study because of the inclusion in the Victorian plots of creek-side vegetation over large areas, and lack of knowledge of the extent of thinning.

Davidson (1976) reported on a brief survey carried out in Kowen Forest, in the Australian Capital Territory, during a nine-week period in summer. The plots used were comparable in ages to those used here but they were much larger and in all cases contained watercourses with native vegetation along them. Davidson's comments on species common to both his and my studies agree with my experience in some cases but are opposed in others. He quoted brown thornbills as common in all plots and as feeding at all heights: I agree if Tasmanian and brown thornbills (very similar species with a considerable overlap of habitat) are treated together. Davidson found that grey fantails occurred only among native trees: that was not true in my study, nor was his finding that the grey shrike-thrush was less common in the older pine plantations. He also reported that silvereyes foraged high in the trees as well as in the undergrowth in all pine plots but were uncommon in native forests: in my study they were seen only occasionally in pines but were frequently seen in all native forests.

A study in Bathurst district of New South Wales in one plot of wet sclerophyll forest, one plot of dry sclerophyll forest and one plot of 18 year old pines was reported by Disney & Stokes (1976). They listed only those species of birds found breeding and it was not stated that nesting was confined to the pines; it is probable that some species nested in trees and undergrowth along watercourses which occurred within the pine plot. Gepp (1976) reported on a study in an exotic forest in South Australia, emphasising the difference in the number of sightings at the edge of plots compared to those well inside the plots. This difference is most noticeable in unthinned and middle-aged pines. In this study care was taken to exclude edges of plantations to avoid such influences.

Fielding (1976) reported on brief visits to a number of pine plantations of varying ages in several districts of Tasmania. His findings are not inconsistent with results herein.

From a study in highland country in New South Wales, Driscoll (1977) found that the number of bird species is similar in pine plantations of varying ages but is less than in native forests.

Friend (1982) found, in a study of bird populations in exotic pine plantations and eucalypt forests in Gippsland, Victoria, that the highest numbers of birds in dense, middle-aged plots were restricted to the edges. Areas of native forest, dams and clearings within pine plantations added to the diversity of habitats and provided more individuals and species of birds. Ecotonal areas were most important.

The yellow-tailed black-cockatoo is not mentioned in the Results section of this paper because it was not seen in the pine plots during this study, although there was clear evidence that this species had torn open dead pines, both standing and lying, in four of the plots.

The number of species of birds in each of the pine plots was similar, except for Plot 1 which had a greater number - possibly because of the increased undergrowth. Similarly, there was a like number of species in each of the native forest plots. There was little variation in the number of bird species found in the younger plantations of pines, whether thinned or unthinned.

One aspect of this study differs from studies in other States. I found only one nest in pine plantations, that of a White's thrush, whereas other studies referred to above have indicated that a number of species nest in pines regularly.

BIRD ECOLOGY OF PINE PLOTS

Insectivorous species found feeding mostly on the trunks and foliage of the pines were the grey shrike-thrush, brown and Tasmanian thornbills and silvereyes, while those feeding on the ground litter included White's thrush, blackbird, all four robins and the white-browed scrubwren. The last-named and the superb fairy-wren were observed only in the undergrowth, where any occurred, but not in soft tree-ferns. The Tasmanian thornbill also fed in the undergrowth but not exclusively.

White's thrush was seen in five of the six pine plots and was found nesting in one. Except in Plot 3 they were not seen frequently but I believe they were residents although difficult to see because of their cryptic colouration and secretive nature. In Plot 1 where I did not record them in the pines, a pair were seen in the native forest nearby and it is likely that they were also in the pines which had extensive ground cover for them.

Plot 4, although almost as old as Plot 1, had only been first-thinned so that less daylight penetrated and there was much less undergrowth. As a result the superb fairy-wren was seen much less frequently here and on only one visit were the blackbird and Tasmanian thornbill observed in the undergrowth.

Nectar-feeding birds, such as honeyeaters, were absent, presumably because of the lack of blossoms. Honeyeaters to some extent eat insects also but it is assumed only those normally associated with nectar. The only honeyeater recorded in the pines was an eastern spinebill on a blackberry bush.

Forest ravens were seen in all plots, mostly in the tops of trees and believed to be passing through but sometimes foraging in the ground litter. They were excluded from my counts unless believed to be feeding.

Green rosellas extracted seeds from pine cones on the trees but not from those on the ground. Brush bronzewings may feed on fallen seeds though only once was this species seen in the pines during this survey.

Only one owl was recorded: a southern boobook was heard calling in Plot 1 at 0600 hours on 18 March 1982.

On one occasion three species were seen to fly in to Plot 5 from adjacent pasture seeking shelter from a heavy rainsquall accompanied by high winds. These three were seen in the plot on only one other visit.

The interstate migrants - silvereye, grey fantail, fan-tailed cuckoo, shining bronze-cuckoo and black-faced cuckoo-shrike - were absent during late autumn and winter. There was also a local migration in autumn and winter which brought some species into the pines - scrubtit, pink robin and dusky robin - and others into the native forests only - grey butcherbird, strong-billed honeyeater, crescent honeyeater and grey currawong. Scrubtits fed in the pines at heights of 3-6 m in Plot 6, but only in undergrowth in Plot 1.

CONCLUSIONS

The often-quoted opinion that pine plantations are "biological deserts" is unfounded, but this study showed that the avifauna in pines is restricted to insectivores which forage for insects in the pines and the pine needle litter on the ground, and to a lesser extent to seed eaters. Many insectivores do not find their food in this habitat.

There was a greater number of bird species in Tasmanian native forests than in pine plantations, and in the latter the number appeared to increase with the amount of undergrowth. Plantations between ten and twenty-five years old, with closed canopies and virtually no undergrowth, appeared least attractive to birds.

To maintain the greatest possible number of bird species it is important that pine plantations should be composed of small plots of varying ages and that these be interspersed with plots of native forest to provide adequate reservoirs of birds and adequate nesting sites. Several bird species require hollows in trees for nesting sites; these are not available in pines, and only in native trees of considerable age (say, over fifty years). Native forest plots should be at least ten hectares in area.

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STRUCTURAL AND FLORISTIC VARIATION IN THE FOREST COMMUNITIES OF THE WEST TAMAR, TASMANIA.

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(with three tables and five text-figures)

ABSTRACT

BROWN, M.J. & BUCKNEY, R.T., 1983 (31 viii): Structural and floristic variation in the forest communities of the West Tamar, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 117: 135-152. ISSN 0080-4703. National Parks & Wildlife Service, P.O. Box 210, Sandy Bay, Tasmania and School of Life Sciences, N.S.W. Institute of Technology, P.O. Box 123, Broadway, New South Wales.

The forest communities in the West Tamar were sampled by a stratified random process using 55 plots selected after preliminary analysis of 243 Forestry Commission continuous forest inventory plots, which occur in the area.

A total of 13 floristic units were recognised and described. The relationship of the floristic units to changing water availability, drainage, soil fertility and fire frequency are assessed and the problems of structural versus floristic classifications of forest types are discussed.

INTRODUCTION

The dry forests of Tasmania occupy some of the most heavily utilised areas of the state. Clearing for agriculture and urban development, sawlog extraction, firewood getting and burning combined with stock grazing have all made their mark on this vegetation. The extent of relatively undisturbed dry forests has been reduced also by the establishment of softwood plantations of *Pinus radiata* and by the advent of the export woodchip industry. There are only comparatively small areas of dry forest vegetation contained within State Reserves (e.g. Jackson 1974). It is apparent that the remaining dry forests can only retain their integrity if there is sound management based on adequate ecological knowledge and description.

Descriptions of the drier lowland forests in the south and east of the State are accumulating. The vegetation in various parts of the Eastern Tiers has been discussed by Kirkpatrick (1981), Kirkpatrick *et al.* (1980), Wells *et al.* (1977), Duncan (1981) and Duncan *et al.* (1981). Accounts are also available of the dry forests on Maria Island (Brown & Bayly-Stark 1979a) and Schouten Island (Harris & Kirkpatrick 1982). Descriptions of forests in other areas of southeastern Tasmania have been given by Jackson (1965), Hogg and Kirkpatrick (1974), Ratkowsky & Ratkowsky (1976, 1977), Harris & Brown (1980) and Brown & Bayly-Stark (1979b). There are no equivalent descriptions published of the drier forests of northern Tasmania, but the need is evident.

In 1978, the Tasmanian Forestry Commission, Department of Environment and National Parks and Wildlife Service undertook jointly to conduct a survey of State Forests in an area bounded by the Bass Highway, Rubicon River and Tamar River (the West Tamar region, fig. 1). The aim of this survey was to provide base data for the evaluation of the potential impact on flora and fauna of proposed pine plantations in the region. An internal report was subsequently produced, but is not generally available. The present paper reports an analysis of the structural and floristic variation found in the forests of the region during that survey.

FIG. 1 - The West Tamar region, showing intensive sampling sites and extent of State Forest.

THE STUDY AREA

The West Tamar region (fig. 1) is bounded to the west by Port Sorell and the Rubicon River, to the south by the Bass Highway, and to the east by the Tamar River. The region has a temperate maritime climate (Langford 1965) but shows pronounced differences between coastal and inland/upland sites. The differences are recognised by Gentilli (1972) who categorised the region as moist subhumid warm (coastal), humid warm (inland) and humid cool (upland). The variations in temperature and rainfall throughout the study area are approximated by the data given in table 1 for Low Head, Mt Pleasant and Deloraine.

The surface geology of the region is diverse (McClenaghan & Baillie 1975). An unmetamorphosed sequence of interbedded Precambrian quartzwackes and phyllites occurs within the Dazzler and Asbestos Ranges. A variety of metamorphosed igneous and sedimentary rocks of Precambrian age occur near Port Sorell and Beaconsfield. Ordovician siltstones, mudstones, sandstones and limestones are found in the Cabbage Tree Hill area and at Flowery Gully. Quartzites and slaty siltstones of Silurian-Lower Devonian age occur near Frankford. The Parmeener Supergroup (unmetamorphosed marine sediments) is represented near Frankford, Glengarry and Beaconsfield. Triassic sandstones and mudstones of fluviatile origin are

TABLE 1

CLIMATIC DATA FOR SELECTED STATIONS NEAR THE STUDY AREA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
LOW HEAD (Coastal, elevation 28 m) 41°3'S, 146°47'E													
A	37	38	41	55	66	80	79	71	60	60	46	46	681
B	8	7	9	11	13	15	17	16	15	13	11	19	145
C	20.6	21.3	20.0	17.7	14.6	12.8	12.1	12.8	13.8	15.4	16.9	18.7	16.4
D	13.2	13.5	12.3	10.7	8.3	6.9	6.0	6.4	7.4	8.7	10.3	11.7	9.6
MT PLEASANT (at Launceston, 50 km inland, elevation 140 m) 41°28'S, 147°9'E													
A	43	54	45	61	79	76	95	99	70	64	54	57	797
B	7	6	8	11	12	13	16	16	14	11	11	9	134
C	23.2	24.0	21.2	17.5	14.0	11.6	11.2	12.3	13.9	16.7	18.5	20.6	17.1
D	10.9	11.7	9.8	7.8	5.1	2.8	2.5	3.6	5.0	5.9	7.8	9.9	6.9
DELORAINE (45 km inland, elevation 253 m) 41°31'S, 146°38'E													
A	45	68	50	87	104	98	144	150	101	82	61	71	1061
B	8	8	9	14	14	14	18	19	16	13	12	12	157
C	22.7	22.3	20.2	16.2	12.9	10.9	10.5	11.3	12.4	15.2	16.8	19.0	15.9
D	9.6	10.3	8.7	6.2	3.1	2.2	1.5	2.8	2.8	4.5	6.2	7.2	5.4

A = precipitation (mm); B = number of raindays; C = mean daily maximum temperature (°C); D = mean daily minimum temperature (°C).

found near Parkham. The southern half of the study area is dominated by Jurassic dolerite. Isolated patches of Tertiary sediments occur widely in the lowland areas and extensive Quaternary deposits have been laid down by the present river systems.

The region has been divided into land systems by Pinkard (1980), who provides detailed descriptions of the land units which occur there. The topography is generally hilly in the north, being dominated by the Asbestos and Dazzler Ranges, which rise to 520 m. In the south, the land surface is more undulating at an average altitude of 150-200 m, but reaching 500+ m on some hills. A map of the vegetation (after Kirkpatrick & Dickinson, 1983) is shown in fig. 2.

The approximate area of State Forest in the region is 38 400 ha. Existing pine plantations occupy 1 700+ ha of State Forest and the establishment of a further 2 200 ha of such plantations is planned by 1990. The remaining 34 500 ha of State Forest are to be managed primarily for hardwood extraction for the sawlog and woodchip industries.

MATERIALS AND METHODS

A two-stage process was used for sampling the forests in the region. The forests were classified initially using the Forestry Commission data from 243 continuous forest inventory (CFI) plots, established in the region. CFI plots are permanently marked, randomly allotted locations, 0.2 ha in area, within a stratified system of forest types determined by photographic interpretation (PI). In addition to the standard forestry data collected for estimates of volume and growth, the height, coverage and species of eucalypts are listed for each plot, and the understorey and ground vegetation are recorded in broad floristic groups characterised by one or several commonly occurring species considered by the Forestry Commission to be indicative of the sites (Anon. 1977). For example, the "wet sclerophyll" group (As, table 2), is characterised by the presence of such species as *Pomaderris apetala*, *Olearia argophylla*, and/or *Phebalium squameum*.

FIG. 2 - Vegetation of the West Tamar region (after Kirkpatrick & Dickinson, 1983). 0 - cleared land; 1 - coastal dune complex; 2 - heath; 3 - woodland; 4 - grassy forest on dolerite; 5 - heathy forest; 6 - *E. obliqua* (tall) open-forest; 7 - *E. delegatensis* tall open forest; 8 - *E. regnans/E. obliqua* very tall open-forest; 9 - complex of eucalypt forest with varying understorey and rainforest.

TABLE 2

CHARACTERISTICS OF THE VEGETATION.
Data obtained from the continuous forestry inventory
plot sheets and used in the initial analysis of 243 sites.

(A) HEIGHT OF DOMINANT VEGETATION

Native eucalypts: 45-60 m (E2); 30-45 m (E3); 12-30 m (E4)

(B) EUCALYPT SPECIES

Eucalyptus obliqua (obl); *E. amygdalina* (amy); *E. delegatensis* (del); *E. ovata* (ova); *E. viminalis* (vim); *E. regnans* (reg).

(C) OTHER TREE SPECIES

Acacia melanoxylon (Bt); *Nothofagus cunninghamii* (Mt); *Atherosperma moschatum* (St); *Acacia dealbata/A. mearnsii* (Wt).

(D) UNDERSTOREY SHRUB GROUPS

Pomaderris apetala/Olearia argophylla/Phebalium squameum (As); *Bedfordia salicina/Olearia viscosa/Olearia lirata* (Bs); *Helichrysum dendroideum/Cassinea aculeata* (Ds); other tall scrub on wet sites (Fs); *Banksia marginata/Casuarina* spp./*Bursaria spinosa/Dodonaea viscosa/Exocarpos cupressiformis* (Gs); *Xanthorrhoea australis* (Ks); *Dicksonia antarctica* (Ms); *Pultenaea juniperina/Epacris* spp./*Lomatia tinctoria/Aotus ericoides/Dillwynia* spp./*Daviesia* spp. (Ps); *Leptospermum* spp./*Melaleuca* spp./*Callistemon* spp. (Ts); *Acacia verniciflua* (Ws).

(E) GROUND SPECIES GROUPS

Bauera rubioides (Ag); *Pteridium esculentum* ± herbs (Bg); *Gahnia* spp. (Cg); *Senecio* spp. (Fg); grasses and herbs (Gg); *Blechnum* spp./*Polystichum proliferum* (Hg); Bryophytes (Mg); *Lepidosperma* spp./*Lomandra longifolia/Diplarrena moraea/Dianella* spp./*Juncus* spp. (Sg); *Histiopteris incisa/Hypolepis* spp. (Wg).

A total of 32 characters were available for the initial analysis. These consisted of three PI height classes and the presence or absence of six eucalypt species, four other tree species, ten understorey shrub groups, and nine ground layer groups (table 2). These data were analysed by the monothetic divisive programme DIVINF, using normal (sites by attributes) and inverse (attributes by sites) analyses to produce a two-way table of sites and attributes. Cut-off levels were selected arbitrarily at 25 groups for sites and 15 groups for attributes.

Two plots were selected to be representative of each of the 25 site groups for subsequent intensive field sampling. Selection of the plots was made on a stratified random basis to ensure geographical and geological coverage of the study area. These 50 plots were supplemented by a further five selected to include forested vegetation types not represented by the CFI plots. There were thus 55 plots included in the field sampling; their locations are given in fig. 1.

The height, composition and percent coverage of each stratum of vegetation at each plot was recorded, together with nature and age of any disturbances evident, including recent fires. The vegetation on each plot was assigned to a structural alliance following the system of Specht (1970), except that a category called "very tall open-forest" was added to include forests in which the average dominant heights of trees exceeded 45 m. A collection of the 328 vascular plants present was made and voucher specimens are held by N.P.W.S. Botanical nomenclature follows Curtis (1963, 1967), Curtis & Morris (1975) and Willis (1970) except when authorities are given. Notes were made also about the aspect, topography, rock type, soils, drainage and ground surface coverage at each plot.

Species presence-absence data from the 55 field plots were classified to produce ten groups using the programme MULTBET. This programme produced an agglomerative classification of sites by the 203 species which occurred in two or more plots. The classification is based on a matrix of similarities determined from the information statistic. The programme GROUPER was run to determine those species which contributed maximally to the clustering of groups. The programmes DIVINF, MULTBET and GROUPER are all contained within the TAXON library (Dale *et al.* 1979), available on the CSIRO CYBER 76 computer.

RESULTS AND DISCUSSION

1. Computer Analyses

The preliminary classification resulting from the DIVINF analysis is shown in fig. 3. The classification provides a logical structural grouping of plots on a basis of the average dominant height class and the presence and absence of indicator species of eucalypts and of "dry sclerophyll shrubs" (Gs). The groups were found to be in broad concurrence with the range of variation of forest types traversed during the field survey.

A dendrogram showing the relationships among the 55 field plots sampled is presented in fig. 4. The plots were classified arbitrarily to the ten-group level, which corresponds closely with the point at which there is an exponential increase in information gain. However subsequent examination of the floristic variation within the groups indicated that two groups were heterogeneous. These groups were subdivided to give a final total of 13 floristic units for the forests within the region. Table 3 details the classification of the sites resulting from the MULTBET analysis and shows the occurrence of diagnostic species by sites. The species in this table are those determined by the GROUPER analysis to have contributed maximally to the fusion of particular groups. Some species are included more than once because they are used at more than one level of the classification. A feature of the characteristic species is the absence of eucalypts, excepting *Eucalyptus ovata*. The lack of continuity between the occurrence of particular eucalypts and of particular floristic units is emphasised in the descriptions of the floristic groups recognised by the MULTBET analysis.

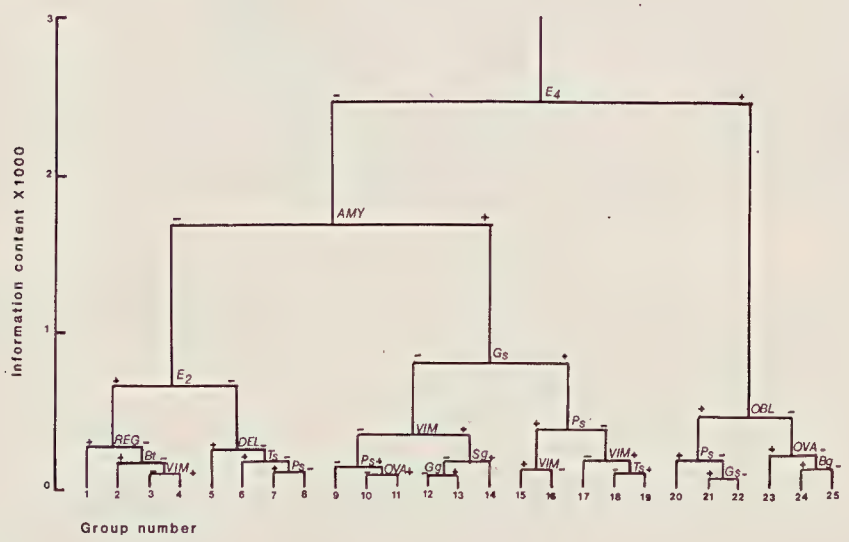

FIG. 3 - DIVINF analysis of the 243 continuous forest inventory plots. The characters on which divisions are made are abbreviated as in table 2.

2. Descriptions of the 13 Floristic Units

Summary descriptions of the 13 floristic units are given in the appendix.

3. Ecological Relationships Among the Plant Communities

The vegetation in the study area responds to diverse but interacting environmental conditions. However, the major responses can be described in terms of soil fertility, water availability, drainage and fire history.

The role of site factors other than fire

Soil fertility is a compounded variable which is broadly related to the mineral content of the geological substrate. However, local climate, topography and past geomorphological processes interact with the vegetation of the site and the weathering characteristics of the particular rock type to produce variations in the soil fertility. In the study area, the siliceous soils are the least fertile, and soils derived from dolerite and the recent river alluviums are the most fertile.

Water availability is determined partly by rainfall, the water-holding capacity of the soil and by the degree of evapotranspirational stress at the site. In general, north and northwest aspects have lower water availability than east and southeast facing slopes and gullies because they lie in the path of prevailing winds and are subject to greater insolation. Gullies and sheltered east to southeast slopes also receive more local rainfall due to wind shadow effects. Water availability is increased also on ridges at higher altitudes, both through orographic rainfall and through reduced transpiration of plants caused by the relatively high frequency of low cloud along the ridges. The drainage of

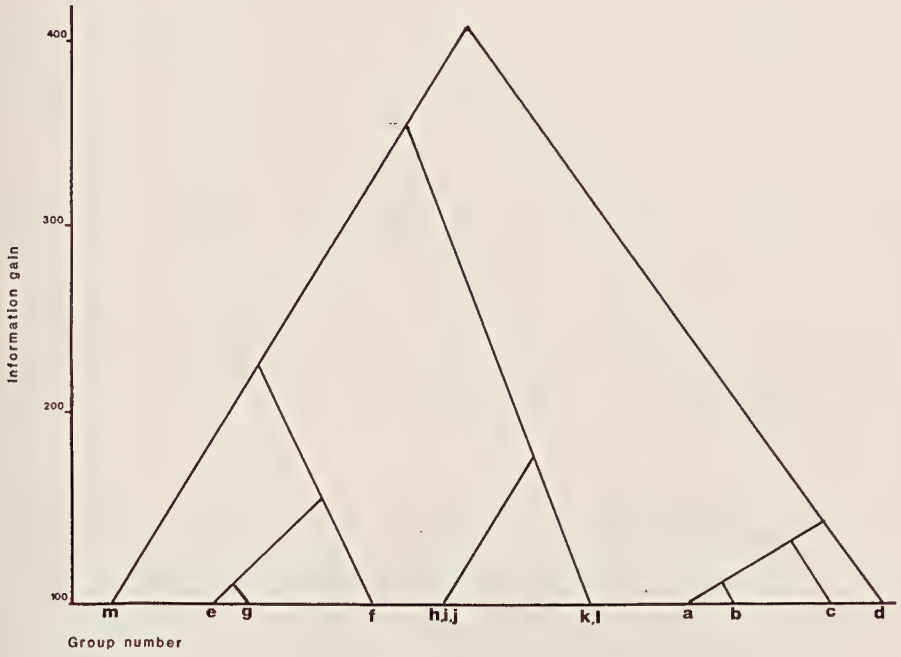

FIG. 4 - MULTBET classification of the 55 sites sampled in the field survey. The characteristic species of the floristic groups a-m are given in table 3.

TABLE 3

TWO WAY TABLE OF SPECIES AND PLOTS.
Plots are arranged left to right in ascending numerical order.

Species	Floristic Unit												
	a	b	c	d	f	e	g	m	j	i	h	k	l
Astroloma humifusum	++ +++++	+++	++++	+ ++	+ +								
Diplarrena moraea	+++ ++	+	+ +	++++									
Bossiaea prostrata	++ +++?+	+++		+ +									
Acrotriche serrulata	+ ++++++	+++	++++	++++	++ +							++	++
Viola hederacea	++++++++	+++	++++	++++	+++++	+++++	+ +				+	+	+
Hypericum japonicum				++++	+	+							
Gnaphalium collinum				+++	+	+++ +	+	+		+	+ +		
Carex breviculmis	+	+		++++									
Veronica calycina		+	++	++++	+ +	+ +		+			+		
Clematis aristata	+ +	+	+	++++	+	++++	+ +	+ ++					
Bossiaea prostrata	++ +++?+	+++		+ +									
Acacia dealbata	+ ++++	+++		++	+++	++		++					
Acacia stricta	+++++ +	+											
Lomandra longifolia	++++++++	+	+++++	++ +	+++++	++		+			++	++	+ ++
Coprosma quadrifida		+++		+ +	+++	+++	+	+++ +					
Acacia botrycephala			+							+	++	+++	++ +
Amperea xiphoclada			+						+	++	+	+++	+
Leptospermum scoparium	+ +		+				+ +		++	+	++	+++	++++
Leucopogon ericoides			+									+++	++++
Tetratheca pilosa	+++ ++	+	+++++	+ +								+ +	++ +
Leucopogon australis												+++	++
Zieria arborescens						+ ++		+++	+	++++	++		
Coprosma quadrifida		+++		+ +	+++	+++	+	+++ +					
Oxalis corniculata	+ ++ ++	+++	+	++++	++++	++++	++	+					
Clematis aristata	+ +	+	+	++++	+	++++	+ +	+ ++					
Pomaderris apetala					+	+ ++	+	+++++					
Polystichum proliferum					+	++		+++++					
Acaena novae-zelandiae	++ + +		++	++	+++	+ +	+ +	+					

Viola hederacea	++++++++	+++	++++	++++	+++++	+++++	+ +				+	+	+
Hydrocotyle javanica	+ ++++	+++	+++	++++	+++	++++	++			++	+		+
Acacia verticillata	+ ++ ++	+			++ +	+ ++	+++				++ +		+++
Epacris impressa	++++++++	+	+++++	+++	+++++	++	++			+++	++++	+++	++++
Dianella tasmanica	++ +		+++++	+ +	++ ++	+ +	++			+ +	+++	+	+
Eucalyptus ovata	+ + +++	+		++		+ +	+++					+	
Blechnum nudum	+				+++++		+	++		+	+ ++		
Gonocarpus teucrioides	+		+ +	+	+++++	+			+	+++	++++	+	+ +
Tetratheca pilosa	+++ ++	+	+++++	+ +								+ +	++ +
Lomandra longifolia	++++++++	+	+++++	++ +	+++++	++		+			++	++	+ ++
Lomatia tinctoria	+++++ ++	+++	++ ++	+ +							++++		+++
Luzula flaccida		++		+++	++++	++++					+		
Geranium solanderi			++	++ +		++++							
Zieria arborescens						+ ++		+++	+	++++	++		
Pultenaea daphnoides				+		++ +				+	++++	+	+
Acacia melanoxylon	+		+++	++ +	++ +	++ +		+++++		+	+ +		+
Olearia lirata	+ +				+++++	+++		++			++		
Triglochin procera							+++						
Lepidosperma elatius	+ +		+				+++					+	
Leptocarpus brownii							+ +					+	
Scirpus cernuus							+ +						
Plantago coronopus				+			++						
Leptospermum lanigerum	+++		+ +				++						
Leptospermum scoparium	+ +		+				+ +		++	+	++	+++	++++
Dicksonia antarctica								+++++		+			
Grammitis billardieri								++++					
Polyphlebium venosum								++++					
Rumohra adiantiformis								++++					
Olearia argophylla								+++++					
Polystichum proliferum					+	++		+++++					
Dianella tasmanica	++ +		+++++	+ +	++ ++	+ +	++			+ ++	++	+	
Persoonia juniperina	+ ++		+++++	+	++						++	++	++++
Pultenaea juniperina	+ + ++		+++++	++	++ ++	+				+++	++		++

sites is conditioned by the interaction between the geological substrate, the physical and chemical properties of the soil, the local topography and the vegetation.

The relationship between the different floristic units of the forests which occur in the study area and the sum of the above environmental determinants is demonstrated schematically in fig. 5. For completeness, structural forms of vegetation other than those surveyed, but which are known to occur in the region (e.g. Kirkpatrick 1977) have also been included in this figure. The numbers in the figure do not refer to actual plot locations or floristic units, but represent sites with similar soil, drainage and moisture characteristics. For example, circle number 1 represents all sites having the characteristics of high soil fertility, good drainage and high water availability. The vegetation types on such sites correspond to floristic unit "m", i.e. are either closed forests of *Nothofagus cunninghamii* and *Atherosperma moschatum* in gully corridors or very tall open-forests of *Eucalyptus regnans* and/or *E. obliqua* with a dense understorey of mesophytic shrubs such as *Acacia melanoxylon* and *Olearia argophylla* together with epiphytic ferns and a layer of *Dicksonia antarctica* and *Polystichum proliferum*.

Circle number 2 represents well-watered, freely draining sites of intermediate soil fertility such as is found on the Precambrian phyllite-dominated rocks of the Dazzler ridges. Tall open-forest of *Eucalyptus delegatensis* and/or *E. obliqua* with a wet sclerophyll-scrub understorey occurs on these sites (floristic unit i). Circle number 3 represents freely draining sites having high water availability but low soil fertility - for example the Precambrian ridges along the Dazzler Range where quartzwacke predominates. Such sites are characteristically occupied by floristic unit j. As one further example, circle number 19 represents fertile sites of high water availability and impeded drainage, for example on some lowland alluvial flats, where a form of floristic unit g (closed scrub) containing *Melaleuca ericifolia* and *Acacia melanoxylon* is found.

In general, these different types of vegetation intergrade along topographic sequences in response to gradients of soil fertility, water availability and drainage. Nevertheless, other influences such as fire, temperature differences associated with altitude, frost hollows or areas of cold air drainage may locally outweigh the factors discussed above and give rise to local variations in the flora. However the most important deflecting influence is fire.

The role of fire

Fire has been and remains a major influence on the vegetation and its effects must be superimposed onto the above scheme. The interaction between the vegetation and the fire regime at a site acts in two different ways.

Firstly, the interaction stabilises and emphasises the difference between structural units. In the study area, the average fire frequency in the different vegetation types is probably as follows: rainforests in gully corridors >100 years; shrubby wet very tall open-forests 20-100 years; scrub 8-20 years; shrubby open-forest 8-15 years; heathy woodland to open-forest 5-10 years; grassy woodland to open-forest 2-8 years; heaths 3-15 years. The actual fire frequency within these classes is determined by a combination of vegetation characteristics (fuel and moisture loadings), site factors (climate, aspect, topography) and the occurrence of an ignition source.

Secondly, the interaction may produce deflected floristic associations within a particular vegetation type. Chance plays a major part in this process. Two sites which are floristically similar may appear very different because of the altered abundance of species within them. Local changes in the abundance of species are as attributable to fire history as they are to other influences. The time interval between fires, the intensity of successive fires, the time of year of the burn and the nature of the fuel loads in surrounding vegetation will vary from place to place. These variables in turn influence the availability of seed in different species, the suitability of the site for the propagation of each species and the ratio of seed to vegetatively propagating species (cf. Purdie 1977a,b), thereby altering the relative abundances of the different species. Due to the feed-back between fire regime and the nature of the vegetation, local changes can initiate a process of ecological drift (Jackson 1968). Thus differences can become

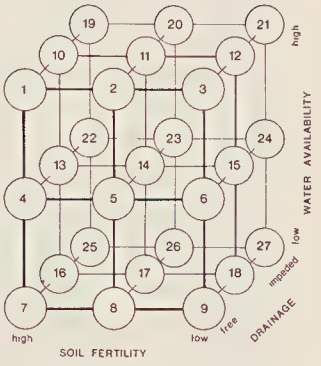

FIG. 5 - Schematic representation of the relationships of plant communities to inferred gradients of soil fertility, drainage and water availability. The encircled numbers are keyed as listed below. The eucalypts are abbreviated as in table 2. C - closed, F - forest, H - heath, L - low, O - open, S - scrub, Sg - sedgeland, T - tall, V - very, W - woodland. Short pricklies (Ps) and saggs (Sg) are defined in table 2.

Number	Structure	Floristic Unit	Dominants	Understorey	Ground Layer
1	CF	m	myrtle, sassafras	mesophytes	ferns, epiphytes
	VTOF		*reg ± obl*	mesophytes	ferns, epiphytes
2	(V)TOF	i	*del, obl*	wet sclerophyll	ferns, sedges
3	LOF,LW	j	*amy*	scrub *(Bauera)*	*Gahnia*
4	TOF	a	*obl-amy*	wattles, dry/wet sclerophyll	grasses, saggs
5	OF	h	*obl-amy*	layered shrubs	grasses/short pricklies
6	LOF	k	*amy*	*Banksia, Casuarina*	heath
7	OF	a	*amy ± vim*	dry sclerophyll	grasses, saggs
8	OF	b	*amy ± vim*	dry sclerophyll	grassy heath
9	H	-	*Xanthorrhoea, Leucopogon*		dry heath
10	TOF	e	*obl, del ± ova*	wet sclerophyll *Callistemon*	ferns, sedges
11	(T)OF	e	*obl,del,vim,amy*	wet sclerophyll	sedges, short pricklies
12	(L)W	c	*amy ± ova*	tea trees	sedges, short pricklies
13	OF	f	*obl,amy,vim ± ova (E.pauciflora)*	dry/wet sclerophyll	short pricklies, sedges
14	OF	d	*obl,amy,vim ± ova*	tea trees, wattles	heath, sedges
15	OW	d	*amy ± ova*	-	heath
16	LOF,W	a	*amy,vim ± ova*	dry sclerophyll	grasses, sedges
17	OF	d	*amy ± ova*	sparse dry	grassy/heath
18	H	-	*Leptospermum,Epacris*	sclerophyll	heath
19	CS	g	*Melaleuca*	sedges	semi-aquatics
20	LOW,CS	g	*ova, Leptospermum*	sedges	semi-aquatics
21	SgH	-	*Lepidosperma,Baumea, Melaleuca*	-	semi-aquatics
22	W	g	*ova*	tea trees	-
23	W,S	g	*ova,* tea trees	tea trees	-
24	LOW	k	*ova*	tea trees	sedges/heath
25	LOF,W	d	*ova*	tea trees	sedges
26	LOF,LOW	k	*ova*		heath
27	H	-	*Sprengelia, Epacris*	-	*Selaginella*

stabilised by chance elimination and/or promotion of particular species, which in turn influences both the nature and likelihood of further fires.

4. The Utility of Structural and Floristic Classifications

The interactions of site factors with the fire regime have important consequences for the classification of forest vegetation in the study area. If a structural classification (based on the dominant eucalypts) is used, then areas which are floristically different may be classified as one type. For example, some of the *Eucalyptus obliqua-E. amygdalina* open-forest of the region has been altered considerably by repeated firing. This community has trees with generally poor form, sparse shrub and ground layers and a dense understorey of bracken. On the dolerite substrates of the southwestern part of the region, such seral communities contain relict herbaceous and grassy species which strongly associate these with other less disturbed sites on dolerite. In contrast, the same structural forms having dense bracken on siliceous substrates in the northeast of the study area contain relict heath species. These sites clearly have floristic affinities with other siliceous-based heathy forests which have not been excessively degraded.

Conversely, if a floristic classification is used, vegetation types having very different physiognomies would be grouped together. For example, relatively undisturbed communities of *Eucalytpus obliqua-E. delegatensis* very tall open-forests have a dense tall shrub understorey. More recently burnt sites support an understorey with a few sparse tall shrubs over a dense layer of bracken, but with young wet sclerophyll shrubs underneath. The latter case will often represent a seral stage of regeneration but the structural heterogeneity may also be more or less permanent, due to the pyrogenic nature of bracken. An increase in the frequency of fires in such a bracken community may result in an ecological drift towards a floristically dissimilar (e.g. heathy) understorey. The types of problems arising from use of the alternative classifications appear to be inherent in the nature of the vegetation-environment processes. They are certainly not unique to this study. Similar disparities have been noted and discussed by Hogg & Kirkpatrick (1974) for the East Risdon area, and by Harris & Kirkpatrick (1982) for Schouten Island. The achievement of an adequate means of typification of Tasmania's dry forests remains central to the needs of both plant ecologists and land managers.

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APPENDIX

A SUMMARY DESCRIPTION OF THE 13 FLORISTIC UNITS.

(a) GRASSY (SEDGEY) TALL OPEN-FOREST

Habitat: fertile loams and clay-loams of varying drainage at medium high elevations on dolerite, at low attitudes on Permian mudstones and on serpentinite.

Eucalypt alliances: *Eucalyptus amygdalina* ± *E. obliqua* ± *E. viminalis* ± *E. ovata* (tall) open-forest.

Average number of species: (31-)47(-67).

Characteristic species:
Tall shrubs/low trees: *Acacia stricta, A. verticillata, A. dealbata, Melaleuca ericifolia, Banksia marginata, Exocarpos cupressiformis.*
Low-medium shrubs: *Lomatia tinctoria, Epacris impressa, Pultenaea gunnii, Tetratheca pilosa.*
Undershrubs: *Acrotriche serrulata, Astroloma humifusum, Bossiaea prostrata.*
Ferns: *Pteridium esculentum.*
Sedges/saggs: *Lomandra longifolia, Diplarrena moraea, Lepidosperma laterale.*
Herbs: abundant, averaging nine species per 0.2 ha plot.
Grasses: abundant, averaging four species per plot.

(b) GRASSY-SHRUBBY OPEN-FOREST

Habitat: shallow-medium clay-loams derived from dolerite, at medium elevations on upper slopes and ridges. Boulders are common.

Eucalypt alliances: *Eucalyptus amygdalina, E. viminalis* ± *E. ovata* ± *E. pauciflora* open-forest.

Average number of species: (44-)51(-61).

Characteristic species:
Tall shrubs/low trees: *Coprosma quadrifida, Acacia dealbata, Exocarpos cupressiformis.*
Low-medium shrubs: *Lomatia tinctoria, Pultenaea gunnii, Pimelea glauca, Leucopogon virgatus.*
Undershrubs: *Acrotriche serrulata, Astroloma humifusum, Bossiaea prostrata, Billardiera scandens.*
Ferns: *Pteridium esculentum.*
Sedges/saggs: none consistent.
Herbs: abundant, averaging 12 species per plot.
Grasses: abundant, averaging five species per plot.

(c) SEDGEY-SHRUBBY OPEN-FOREST

Habitat: on freely draining, shallow sites of the upper slopes and ridges. Boulders and outcrop are common. Soils are either dolerite-derived clay loams or sandy loams on Precambrian rocks.

Eucalypt alliances: *Eucalyptus obliqua* ± *E. viminalis* ± *E. amygdalina* ± *E. delegatensis* open-forest.

Average number of species: (30-)42(-50).

Characteristic species:
Tall shrubs/low trees: *Acacia melanoxylon, Banksia marginata, Exocarpos cupressiformis.*
Low-medium shrubs: *Lomatia tinctoria, Pultenaea juniperina, Epacris impressa, Persoonia juniperina, Pultenaea gunnii, Tetratheca pilosa, Coprosma hirtella.*
Undershrubs: *Astroloma humifusum, Acrotriche serrulata, Billardiera scandens.*
Ferns: *Pteridium esculentum.*
Sedges/saggs: *Lomandra longifolia, Dianella tasmanica, Lepidosperma laterale.*
Herbs: abundant, averaging seven species per plot.
Grasses: scattered to sparse, averaging four-five species per plot.

(d) SEDGEY TALL OPEN-FOREST

Habitat: on shallow, gravelly but fertile clays where drainage is partly impeded, on terraces at medium altitudes on dolerite and on Permian mudstone on lowland flats.

Eucalypt alliances: *Eucalypt viminalis ± E. obliqua; E viminalis ± E. ovata* tall open-forest.

Average number of species: (46-)53(-57).

Characteristic species:
Tall shrubs/low trees: *Exocarpos cupressiformis, Banksia marginata, Cassinia aculeata, Acacia melanoxylon.*
Low-medium shrubs: none consistent.
Undershrubs: *Acrotriche serrulata.*
Ferns: *Pteridium esculentum ± Lindsaea linearis.*
Sedges/saggs: *Gahnia grandis, Diplarrena moraea, Carex breviculmis, Lepidosperma laterale, Dianella tasmanica, Lomandra longifolia.*
Herbs: abundant, averaging 15 species per plot.
Grasses: patchy, averaging 2-3 species per plot.

(E) DRY/WET VERY TALL OPEN-FOREST

Habitat: shallow sandy loams formed from dolerite and Permian mudstones. On the upper midslopes, broad ridges and shallow gullies at medium-high altitudes where available moisture is increased through orographic rainfall or by stripping of fog and low cloud.

Eucalypt alliances: *Eucalyptus obliqua ± E. viminalis ± E. regnans; E. amygdalina ± E. ovata* very tall open-forest.

Average number of species: (30-)40(-49).

Characteristic species:
Tall shrubs/low trees: *Olearia lirata, Pultenaea daphnoides, Zieria arborescens, Pomaderris apetala, Coprosma quadrifida, Acacia melanoxylon.*
Low-medium shrubs: none consistent.
Undershrubs: none consistent.
Ferns: *Pteridium esculentum ± Polystichum proliferum.*
Sedges/saggs: *Luzula flaccida ± Gahnia grandis; Dianella tasmanica, Lomandra longifolia.*
Herbs: abundant, averaging 12 species per plot.
Grasses: patchy-sparse, averaging 4-5 species per plot.

(f) WET/DRY TALL OPEN-FOREST

Habitat: sheltered aspects of upper midslopes, terraces and ridgetops. At higher elevations on free draining clay-loams derived from dolerite, boulders are common.

Eucalypt alliances: *Eucalyptus obliqua ± E. viminalis ± E. amygdalina ± E. delegatensis* tall open-forest.

Average number of species: (41-)47(-53).

Characteristic species:
Tall shrubs/low trees: *Olearia lirata, Bedfordia salicina, Acacia melanoxylon, Coprosma quadrifida, Acacia verticillata, Acacia dealbata, Exocarpos cupressiformis, Bursaria spinosa, Cassinia aculeata.*
Low-medium shrubs: *Lomatia tinctoria, Epacris impressa, Coprosma hirtella, Tetratheca pilosa, Pultenaea juniperina.*
Undershrubs: *Gonocarpus teucrioides, Billardiera scandens, Acrotriche serrulata.*
Ferns: *Blechnum nudum, Pteridium esculentum, Asplenium flabellifolium.*
Sedges/saggs: *Lomandra longifolia, Dianella tasmanica, Luzula flaccida.*
Herbs: common, averaging 9 species per plot.
Grasses: sparse, but averaging 4-5 species per plot.

(g) SCRUB (SCRUBBY OPEN-WOODLAND TO OPEN-FOREST)

Habitat: Quaternary alluviums bordering the larger creeks at low elevations; also in localised pockets on drainage lines at higher elevations.

Eucalypt alliances: *Eucalyptus ovata* ± *E. amygdalina* ± *E. obliqua* open-forest, woodland and open-woodland. Also occurs as closed scrub without eucalypts.

Average number of species: (35-)39(-44).

Characteristic species:
Tall shrubs/low trees: *Acacia verticillata, Leptospermum lanigerum, Melaleuca ericifolia, Cassinia aculeata.*
Low-medium shrubs: *Bauera rubioides, Leptospermum scoparium, Epacris impressa, Pultenaea gunnii.*
Undershrubs: none consistent.
Ferns: *Blechnum wattsii* ± *B. nudum, Gleichenia dicarpa, Pteridium esculentum.*
Sedges/saggs: *Lepidosperma elatius, Dianella tasmanica* ± *Gahnia grandis.*
Herbs: common, averaging 9 species, including some distinctive aquatic species *(Myriophyllum* sp., *Triglochin procera).*

(h) HEATHY DRY/WET OPEN-FOREST

Habitat: freely draining sandy loams derived from Precambrian or Ordovician siliceous rocks. At low to medium elevation on gentle basal and midslopes of hills.

Eucalypt alliances: *Eucalyptus obliqua* ± *E. amygdalina* open-forest.

Average number of species: (33-)36(-39).

Characteristic species:
Tall shrubs/low trees: *Pultenaea daphnoides, Casuarina littoralis, Acacia verticillata, Zieria arborescens.*
Low-medium shrubs: *Lomatia tinctoria, Epacris impressa.*
Undershrubs: *Gonocarpus teucrioides, Billardiera scandens.*
Ferns: *Pteridium esculentum, Blechnum nudum.*
Sedges/saggs: none consistent.
Herbs: sparse, averaging 4 species per plot.
Grasses: sparse, averaging 2 species per plot.

(i) HEATHY-SHRUBBY VERY TALL OPEN-FOREST

Habitat: on clay loams derived from Precambrian phyllite dominated rocks on the upper mid-slopes, ridges and across small dissection gullies of the Dazzler Range.

Eucalypt alliances: *Eucalyptus obliqua, E. delegatensis* very tall open-forest.

Average number of species: (17-)23(-34).

Characteristic species:
Tall shrubs/low trees: *Zieria arborescens, Monotoca glauca.*
Low-medium shrubs: *Pultenaea juniperina, Epacris impressa.*
Undershrubs: *Gonocarpus teucrioides* ± *Amperea xiphoclada.*
Ferns: *Pteridium esculentum* ± *Blechnum wattsii.*
Sedges/saggs: *Dianella tasmanica* ± *Lepidosperma laterale.*
Herbs: none consistent.
Grasses: generally absent.

(j) SCRUBBY LOW OPEN-FOREST

Habitat: on freely draining sandy loams derived from Precambrian rocks where quartzwacke is predominant. At medium elevations on shallow side slopes and flat spurs above small dissection gullies of the Dazzler Range.

Eucalyptus alliances: *Eucalyptus amygdalina* low open-forest.

Average number of species: 13-14.

Characteristic species:
Tall shrubs/low trees: *Banksia marginata, Leptospermum scoparium.*
Low-medium shrubs: *Bauera rubioides, Phebalium bilobum, Dillwynia glaberrima.*
Undershrubs: *Amperea xiphoclada.*
Ferns: none consistent, *Pteridium esculentum* and *Gleichenia microphylla*
Sedges/saggs: *Gahnia grandis.*
Herbs: none consistent.
Grasses: none.

(k) HEATHY LOW WOODLAND

Habitat: on flat marine terraces at low elevations on infertile siliceous soils derived from Tertiary alluvium.

Structural associations: *Eucalyptus amygdalina* ± *E. ovata* low woodland.

Average number of species: (40-)43(-48).

Characteristic species:
Tall shrubs/low trees: *Casuarina littoralis, Banksia marginata.*
Low-medium shrubs: *Epacris impressa, Leptospermum scoparium, Acacia botrycephala, Bossiaea cinerea, Leucopogon australis, L. ericoides, Persoonia juniperina, Tetratheca pilosa, Leucopogon collinus, Pimelea linifolia.*
Undershrubs: *Amperea xiphoclada.*
Ferns: *Pteridium esculentum.*
Sedges/saggs: *Xanthorrhoea* spp., *Lomandra longifolia.*
Herbs: common, averaging 5 species per plot.
Grasses: none observed.

(l) HEATHY-LAYERED (TALL) OPEN-FOREST

Habitat: freely draining sandy loams derived from Precambrian siliceous and Permian mudstone rocks. On upper mid-slopes and ridges of low hills flanking the Dazzler and Asbestos Ranges.

Structural alliances: *Eucalyptus obliqua* ± *E. amygdalina* (tall) open-forest.

Average number of species: (40-)43(-48).

Characteristic species:
Low trees/tall shrubs: *Banksia marginata, Acacia verticillata, Monotoca glauca.*
Low-medium shrubs: *Epacris impressa, Persoonia juniperina, Pultenaea gunnii, Leptospermum scoparium, Leucopogon ericoides, Lomatia tinctoria, Tetratheca pilosa, Acacia botrycephala.*
Undershrubs: *Billardiera scandens.*
Ferns: *Pteridium esculentum.*
Sedges/saggs: *Lepidosperma laterale, Gahnia grandis, Lomandra longifolia.*
Herbs: sparse, averaging 3 species per plot.
Grasses: sparse, only *Tetrarrhena distichophylla* found.

(m) SHRUBBY WET VERY TALL OPEN-FOREST TO RAINFOREST

Habitat: fertile, well drained soils where water availability is high, in the deeply incised gullies on sheltered eastern aspects along the Dazzler-Asbestos Ranges and in deep gorges at lower levels, e.g. Saxons Creek, Holwell Gorge, Notley Gorge.

Eucalypt alliances: ± *Eucalyptus regnans* ± *E. obliqua* ± *E. delegatensis* ± *E. viminalis* very tall open forest. Also without eucalypts in ± *Nothofagus cunninghamii* ± *Atherosperma moschatum* ± *Acacia melanoxylon* closed forests.

Average number of species: (13-)27(-33).

Characteristic species:
Tall shrubs/low trees: *Olearia argophylla, Pomaderris apetala, Acacia melanoxylon, Coprosma quadrifida, Atherosperma moschatum, Zieria arborescens.*
Low-medium shrubs: none.
Undershrubs: none.
Ferns: *Dicksonia antarctica, Polystichum proliferum, Rumohra adiantiformis, Grammitis* sp., *Polyphlebium venosum, Microsorium diversifolium, Hymenophyllum* spp.
Sedges/saggs: none consistent.
Herbs: occasional, e.g. *Clematis aristata.*
Grasses: sporadic, only in disturbed areas.

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ESTIMATION OF SOLAR RADIATION RECEIVED ON SLOPES IN TASMANIA

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(with four text-figures)

ABSTRACT

NUNEZ, M., 1983 (31 viii): Estimation of solar radiation received on slopes in Tasmania. *Pap. Proc. R. Soc. Tasm.*, 117: 153-159. ISSN 0080-4703. Department of Geography, University of Tasmania, Hobart, Tasmania.

A solar radiation model has been used to calculate direct and diffuse solar radiation received on a surface. A series of diagrams are presented which enable the quick calculation of the daily total insolation received by a surface of known orientation.

INTRODUCTION

Solar radiation forms an important parameter in many ecological and botanical studies. In Tasmania many of these studies are conducted in complex topographic terrain which is characterized by highly variable solar energy microclimates. Solar radiation data of this nature cannot be obtained from the available climatological literature, and it is to this problem that this paper is addressed.

Pyranometers are used throughout Australia by the Bureau of Meteorology to collect global and diffuse solar radiation on a unit horizontal surface. However data collected from this network of stations is commonly of little value to Tasmanian researchers who often require to know the mean solar energy incident on a surface with a given slope and aspect. One option is to measure the solar energy directly using a pyranometer tilted at a given slope and azimuth. Whilst this is a perfectly valid technique, the equipment and manpower requirements are usually in excess of the resources available.

At present, theoretical models seem to be the most satisfactory way of calculating the solar energy received on slopes. Studies such as Garnier & Ohmura (1968), Holland & Steyn (1975), and Revfiem (1976) consider only direct radiation incident in sloping terrain. Diffuse radiation has also been incorporated by Rouse & Wilson (1969), Schulze (1975) and Bugler (1975) using empirical techniques.

A more generally applicable model was developed by Nunez (1980) who used cloud cover data to derive direct and diffuse solar radiation incident on a tilted surface of any orientation and limited by sky view factor and shadow effects.

Initially the model was applied as a case study to a mesoscale hilly environment at Risdon, Tasmania. In the present paper the model is used to derive three diagrams which relate solar energy to the slope and aspect of the receiving surface. The diagrams provide a reference base from which the solar radiation incident on slopes of any orientation can be readily estimated.

THE MODEL

The global solar radiation on a horizontal surface (G_C) can be described (Nunez, 1980) as

$$G_C = I_o \tau \cos Z + D \qquad (1)$$

where I_o = solar constant = 1353 Wm^{-2}
τ = transmission of the atmosphere to direct radiation
D = diffuse radiation incident on a horizontal surface (Wm^{-2})
Z = solar zenith angle.

The term τ is a function of Rayleigh scatter, precipitable water vapour and cloud cover at three levels. D is also calculated in terms of Rayleigh scattering and cloud cover. In this paper only the broad outlines of the model are described. The interested reader is referred to the above reference for further details.

In the case of a sloping surface both the angle of incidence of direct radiation and the diffuse component D change from the horizontal case, so that the incoming solar radiation ($K_C\downarrow$) is:

$$K_C\downarrow = \underbrace{I_o \tau \cos \gamma}_{\text{term 1}} + \underbrace{D \, VF}_{2} + \underbrace{G_C \, \alpha(1-VF)}_{3} \qquad (2)$$

VF = sky view factor
α = albedo of surface
γ = angle of incidence of direct radiation

Term 1 denotes the direct radiation received by the surface. Diffuse radiation is represented by terms 2 and 3, term 2 denoting radiation from the sky incident on the surface and term 3 representing diffuse radiation that originates from reflection of global radiation by the ground. the angle of incidence of direct radiation with the inclined surface can be given as:

$$\cos \gamma = \sin Z.\cos\phi.\sin X.\cos Y + \sin Z.\sin\phi.\sin X.\sin Y + \cos Z.\cos X \qquad (3)$$

and Z,ϕ = zenith and azimuth angles for direct solar radiation
X,Y = zenith and azimuth angles for the normal to the surface (see fig. 1).

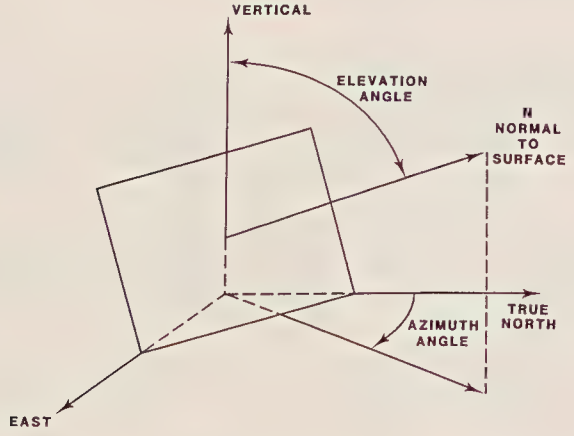

FIG. 1 - Geometry used for estimating insolation on slopes. The vertical intersects the square surface at the midpoint of the diagonals.

VF, the sky view factor varies from 1.0 for a horizontal surface to 0.5 for a vertical surface. Methods for obtaining VF can be obtained readily in the literature (Paltridge 1976, Nunez 1980). Note that the relationship described in equation 3 does not take into account shadow effects. That is, the tilted surface is considered exposed to solar radiation except for limitations imposed by its own elevation and azimuth orientations. This has been done purposely to make the relations as general and widely applicable as possible.

Testing $K_C\downarrow$ in equation 2 is not possible at present since there is no experimental data to compare it with. However Nunez (1980) has shown that estimates of G_C (equation 1) agree to within 5% of the mean monthly value (1971-75) of the daily total of solar radiation for Hobart airport.

In this paper $K_C\downarrow$ is used to derive a series of insolation diagrams for various elevation and azimuth orientations. In deriving this term a value of surface albedo (α) of 0.20

is used representing a mean value between eucalyptus forests and dry grasslands (Paltridge 1975). Cloud data at three levels (low, medium and high) are needed to obtain τ and D. These were obtained as monthly averages of six observations (06, 09, 12, 15 and 18 hours EST) taken from Hobart airport for a five-year period (1971-1975). These were interpolated to give half-hourly values. Monthly precipitable water vapour and cloud base albedo are also needed in τ and D. Monthly mean estimates of precipitable water vapour for Hobart airport were taken from Pierrehumbert (1972). Following Hay (1976) a cloud base albedo of 0.6 was used.

The following procedure was used in deriving the insolation diagrams. A given surface was considered to tilt in 15 degree steps from a horizontal to a vertical position. At each tilt position the surface was rotated through 360 degrees in the azimuth using 15 degree steps. Thus, a total of 85 different azimuth and elevation combinations are considered here. At each of these positions $K_C\downarrow$ was solved for every half hour using the cloud data, solar elevation and azimuth typical of the month. Summing the half-hourly values gave a daily total figure for each position. Solar elevation and azimuth were calculated at the fifteenth day of each month, and it was assumed that they represented mean conditions for that month.

RESULTS

Figure 2 shows the results for December when solar radiation is at a maximum. A highest value of 22.0 $MJm^{-2}day^{-1}$ is estimated along the horizontal This result is somewhat unexpected since direct radiation receipt is at a maximum in north facing slopes of 15 degree elevation. Equation shows why this apparent anomaly occurs. As the surface tilts northwards there is an increase in the direct radiation, plus diffuse radiation originating from surface reflection (terms 1 and 3). However the increase in these two terms is not enough to offset the decrease in diffuse sky radiation (term 2).

In general the trend in figure 2 is one of decreasing solar radiation with increasing elevation. The curves show a lesser dependence on azimuth orientation, and only so at greater elevations ($>40°$) and in south-facing slopes. A lowest value of just under 9.0 $MJm^{-2}day^{-1}$ was obtained for a vertical south-facing surface.

By contrast the June diagram (figure 3) shows a marked dependence on azimuth orientation. Solar elevations are much lower and this makes the azimuth orientation much more critical in determining the angle of incidence of direct radiation. Thus, a maximum radiation of 9.0 $MJm^{-2}day^{-1}$ is obtained in north-facing slopes of 65 degrees elevation. By contrast the south-facing slopes of the same elevation have an insolation of 2.3 $MJm^{-2}day^{-1}$. A lowest value of 1.9 $MJm^{-2}day^{-1}$ is obtained for a vertical south-facing surface.

On a yearly basis both the azimuth and elevation dependence are represented (figure 4). A maximum value of 5.3×10^3 $MJm^{-2}day^{-1}$ occurs on north-facing slopes at elevations of 30 degrees. This value is only slightly higher than the horizontal case (4.8×10^3 $MJm^{-2}day^{-1}$). However a south-facing slope of 30 degrees elevation only receives 3.6×10^3 $MJm^{-2}day^{-1}$ of insolation.

DISCUSSION AND CONCLUSION

The representativeness of the results for other areas in Tasmania must now be considered. Three level cloud data are only available for Hobart airport, so that the model is not easily transposed to other areas. However models using sunshine duration data show that on a *climatological time scale* radiation data vary by at most 10-15% over large areas in central and eastern Tasmania (Hounam 1963, Nunez 1978). It is likely then that the results presented here are applicable over these areas to within 10-15%.

In some cases local topography may block the direct radiation and therefore special models need to be constructed (Nunez 1980). Trees also present a problem is solar radiation data are required at ground level on a forested slope and a model of tree transmission is currently being developed.

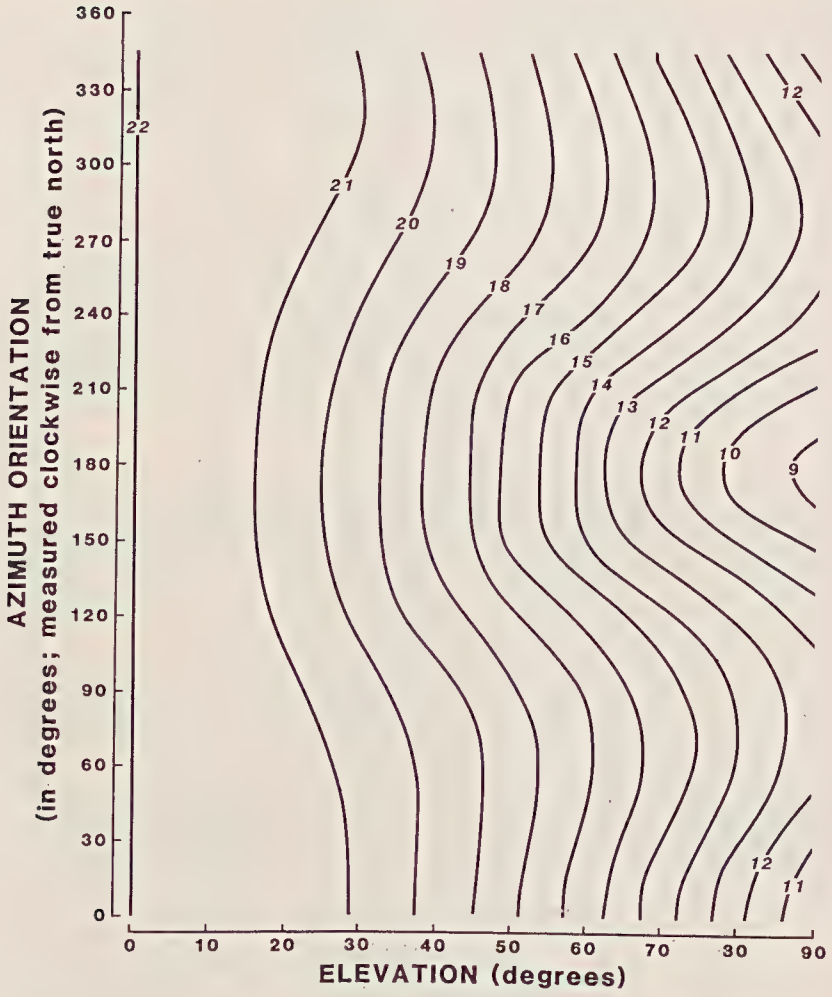

FIG. 2 - Mean daily solar radiation received on a slope ($MJm^{-2}day^{-1}$), December. (Total received on a horizontal surface = 22.0 $MJm^{-2}day^{-1}$.)

Overall, to compensate for the absence of experimental information, these results provide estimates of solar radiation for sloping terrain. Local cloud and precipitable water data are used in a model of atmospheric opacity. The model compares well with measured values of solar radiation on a horizontal surface.

It should be emphasized that monthly climatological data have been used both in cloud cover and precipitable water vapour. These diagrams cannot represent short-term fluctuations, and therefore their use will depend on the objectives of the researcher. Direct measurements are necessary if a research problem involves a definite event of short-term duration. On the other hand, many processes in ecology and botany respond to climatological averages, and in this case the use of these diagrams is justified.

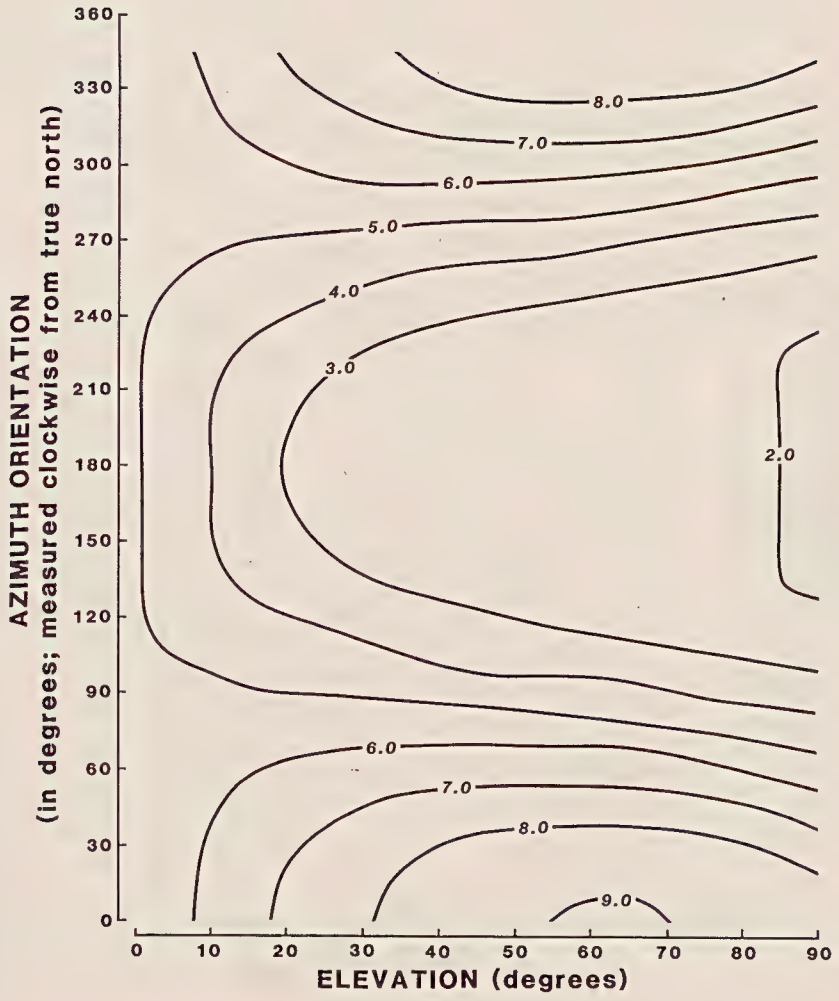

FIG. 3 - Mean daily solar radiation received on a slope ($MJm^{-2}day^{-1}$), June. (Total received on a horizontal surface = 5.1 $MJm^{-2}day^{-1}$.)

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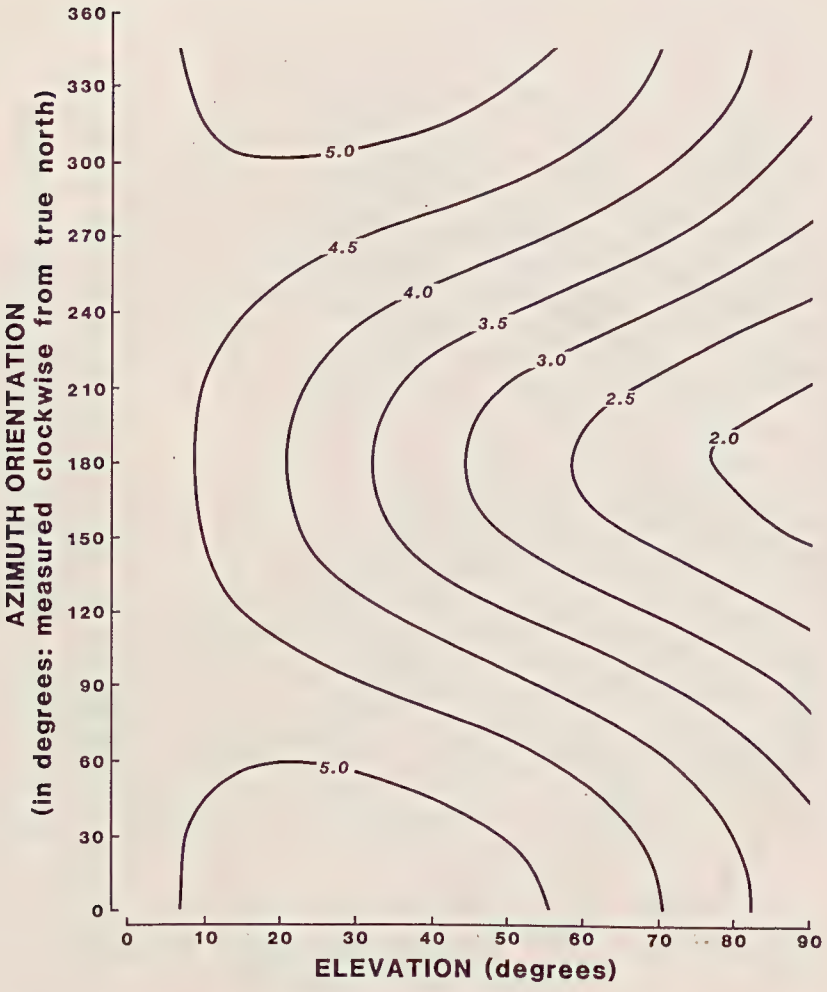

FIG. 4 - Yearly total solar radiation received on a slope ($MJm^{-2} \times 10^3$). (Total received on a horizontal surface = 4.8×10^3 MJm^{-2}.)

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A MASS STRANDING OF SQUID *MARTIALIA HYADESI* ROCHEBRUNNE & MABILLE (TEUTHOIDEA: OMMASTREPHIDAE) AT MACQUARIE ISLAND.

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(with one text-figure)

ABSTRACT

O'SULLIVAN, D.B., JOHNSTONE, G.W., KERRY, K.R. & IMBER, M.J., 1983 (31 viii): A mass stranding of squid *Martialia hyadesi* Rochebrunne & Mabille (Teuthoidea: Ommastrephidae) at Macquarie Island. *Pap. Proc. R. Soc. Tasm.*, 117: 161-163. ISSN 0080-4703. Antarctic Div., Kingston, Tasmania and Wildlife Service, Wellington, New Zealand.

A large number of squid, subsequently identified as *Martialia hyadesi* (Ommastrephidae) was stranded on beaches at the northern end of Macquarie Island, 54°30'S, 158°57'E, on 5 March 1971. The squid were immature, or at least pre-breeding, and had been feeding recently. It is suggested that a sudden change in wind direction, coupled with a rising tide, caused the stranding. This is the first reported stranding of this species, which has not previously been recorded in the Pacific region.

THE STRANDING

On the afternoon of 5 March 1971 a large number of squid came ashore on a rising tide on the shingle beach at Hasselborough Bay (fig. 1) which forms the western shore of a narrow isthmus near the northern end of Macquarie Island (54°30'S, 158°57'E). A few were also found on the eastern shore. The squid were alive but seemed unable to swim out again, though they had not lost the ability to swim. Some were thrown into the light surf but were washed ashore again. Others swam strongly when placed in a container of seawater.

Squid were stranded along at least 400 m of the shore of Hasselborough Bay, where the density was roughly 5 per metre initially. Possibly several thousands of individuals were stranded, but the extent of the strandings and the number of squid involved is unknown.

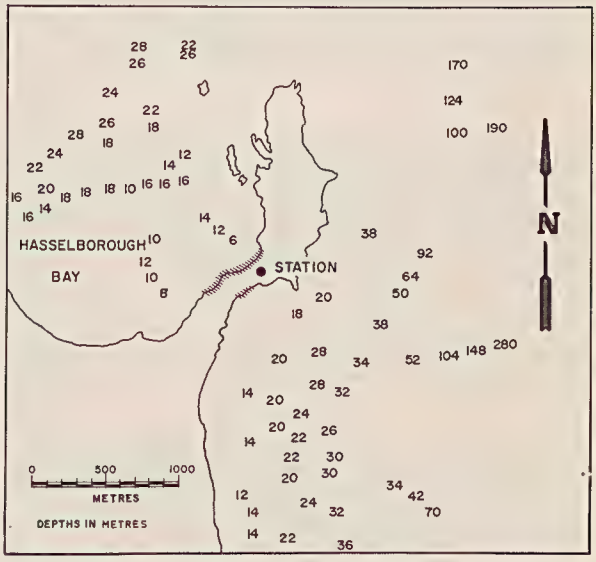

FIG. 1 - Map of the north end of Macquarie Island showing stranding areas (hatched). Depths in metres.

A Mass Stranding of Squid *Martialia hyadesi*.

EXAMINATION OF THE STRANDED SQUID

Thirty squid were collected, frozen and returned to Australia. In 1974, six were deposited at the National Museum of Victoria, and have since been identified as *Martialia hyadesi* Rochebrunne & Mabille by Dr C.C. Lu. In 1976, five others were placed in the National Museum of New Zealand; one of these was independently identified by Dr M.A. Roeleveld, who is revising the family Ommastrephidae, as *M. hyadesi* (pers. comm.).

The rest of the squid remained in the Australian Antarctic Division collection. In 1981 those in the Division collections and those at the National Museum of Victoria were examined for sex, maturity, mantle length and stomach contents. The squid were all immature; only one of the twelve males exhibited hectocotylisation but it had no spermatophores in its Needham's sac. The nidamental glands and ovaries of the thirteen females were not developed. The mantle length ranged from 232 to 292 mm. Each specimen was found to have a full stomach, the contents consisting mainly of macerated crustaceans.

PREVIOUS STRANDINGS

Many species of squid have been stranded (Clarke 1966, p.101,117,127,129,132, Anon. 1976, Prescott 1977, Lux *et al.* 1978), but many incidents involved only one individual (Clarke 1966, p.147,148,161 etc.). Mass strandings are apparently unique to the Ommastrephidae and all species that have stranded inhabit the continental shelf and near shore waters.

Various causes of mass strandings have been suggested but all remain speculative for lack of evidence. They include squid being driven ashore by predators, or strong winds, squid becoming disorientated and losing their way, becoming affected by toxicity in the water or a rapid change in water temperature, pursuing food close to shore, or becoming excited immediately prior to copulation, leading to disorientation (Gillespie 1953, Hamabe & Shimizu 1959, Lux *et al.* 1978).

DISCUSSION

This is the first reported stranding of *Martialia hyadesi* and is among the few records of this squid. The species is a predominantly subantarctic form, being found on and off the continental shelf (between 100 and 300 m) along the Atlantic coast of South America from 39°S down to the Falkland Islands (52°S; Castellanos & Menni 1968). It has not been recorded from the Pacific although Castellanos & Menni (1969) thought it possible that the species originated in the Pacific and moved around Cape Horn to establish the existing population off southern Patagonia and the Falkland Islands.

During current studies at Macquarie Island beaks of *Martialia hyadesi* are being found in the stomach contents of the seabirds *Macronectes giganteus*, *M. halli*, *Phoebetria palpebrata* and *Diomedea exulans*, indicating that *M. hyadesi* is common in the oceans of the region.

The period prior to the stranding (2-4 March 1971) was characterised by persistent strong to gale force onshore winds (NW-WNW) with steady temperatures and low rainfall. On the morning of March 5, the prevailing wind was still a strong WNW but at about 1500 hours the wind direction changed to ESE, an offshore wind of 20-30 kph. It was at about this time that the squid were seen to be coming ashore.

Hasselborough Bay rises from about 28 m to a gently sloping beach. The prevailing current, driven by the West Wind Drift, is easterly and hence onshore in Hasselborough Bay. It is possible that the squid were feeding close inshore and the sudden change in wind direction may have caused changes in the hydrology of the Bay so that the squid were brought into the beach by upwelling currents close to shore. This could have occurred only on the western shore of the isthmus, and the proposed mechanism does not explain the smaller stranding on the eastern shore.

Alternatively, the squid may have become disorientated by a sudden change in wind direction of the surface water, brought about by the change in wind direction. In either case, the rising tide and moderate wave action would have helped to carry the squid onto the beaches and would have hindered any attempt to swim free again.

ACKNOWLEDGEMENTS

We are greatly indebted to several people: to the Director of the Bureau of Meteorology for supplying us with the weather data for Macquarie Island; to Mr R. Williams and Ms R. Horne, Australian Antarctic Division, for their helpful advice; and Dr C.C. Lu, National Museum of Victoria, for identifying the specimens and for criticism of the text. The constructive criticisms of an anonymous referee substantially improved the manuscript.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 117, 1983.

TIDAL IMMERSION OF THE TAMAR ESTUARY *SPARTINA* MARSH, TASMANIA, AUSTRALIA - CORRECTION.

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(with one text-figure)

ABSTRACT

PRINGLE, A.W., 1983 (31 viii): Tidal Immersion of the Tamar Estuary *Spartina* Marsh, Tasmania, Australia - Correction. *Pap. Proc. R. Soc. Tasm.*, 117: 165. ISSN 0080-4703. Department of Geography, University of Lancaster, Lancaster, England.

The explanation of figure 4, inadvertently not printed in Dr Pringle's paper in Volume 116 of the Papers and Proceedings is here provided.

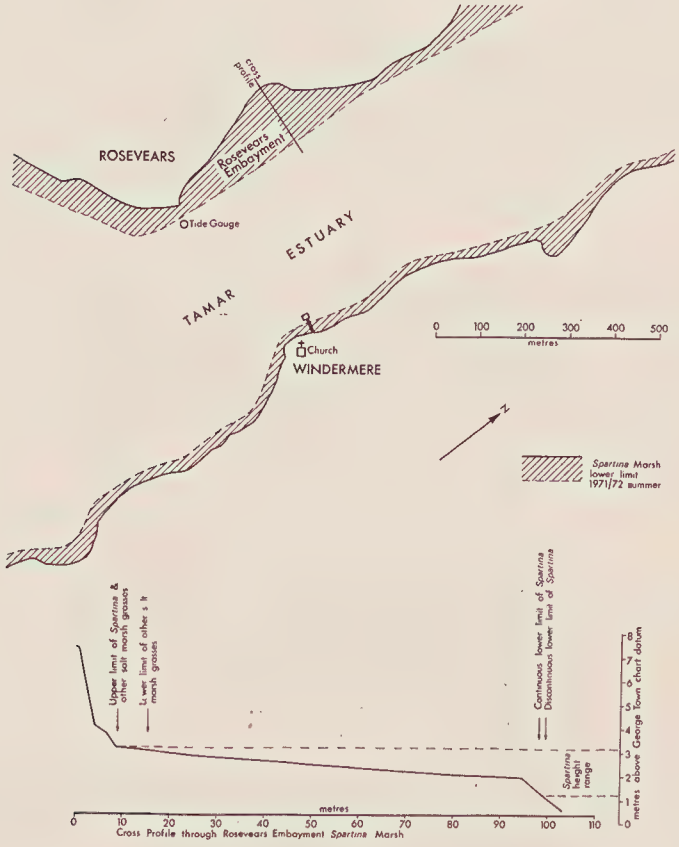

FIG. 4 - Plan and profile of Rosevears embayment *Spartina* marsh.

Papers and Proceedings of the Royal Society of Tasmania, Volume 117, 1983

(ms. received 5.1.1983)

OBSERVATIONS ON SOME TASMANIAN FISHES: PART XXIX

by E.O.G. Scott
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(with two tables, six text-figures and three plates)

ABSTRACT

SCOTT, E.O.G., 1983 (31 viii): Observations on some Tasmanian fishes: Part XXIX. *Pap. Proc. Roy. Soc. Tasm.*, 117: 167-202. ISSN 0080-4703. Queen Victoria Museum and Art Gallery, Launceston, Tasmania.

REGALECIDAE. *Regalecus glesne* Ascanius, 1772: recent local stranding. TRACHIPTERIDAE. A comprehensive study has been made of seven Tasmanian dealfish determined as *Trachipterus arawatae* Clarke, 1881. Unfortunate misapprehensions by Australasian authors of the status of the genera *Trachipterus* Gouan, 1770, *Desmodema* Walters & Fitch, 1960 and *Zu* Walters & Fitch, 1960 have led to widespread and continued confusion regarding dealfishes in the local literature: a chronological synopsis of emended names is provided. the genus *Zu* is here recorded for the first time from Australian waters, a specimen from Stanley being provisionally determined as *Z. cristatus* (Bonelli, 1820). EMMELICHTHYIDAE. *Emmelichthys nitidus* Richardson, 1845: general observations on an example about two-thirds grown. PEMPHERIDAE. *Parapriacanthus elongatus* (McCulloch, 1911): general observations, special reference to coloration. SOLEIDAE. *Zebrias fasciata* (Macleay, 1882): two additional local records; some unusual features.

INTRODUCTION

This paper follows the general plan of others in the series. Linear measurements are given throughout in millimetres, the name of the unit commonly being omitted, or are given as thousandths of standard length. The symbols *Ls*, *Lt*, *TLs*, *TLt* denote standard length, total length, thousandths of standard length, thousandths of total length, respectively. Registration numbers are those of the Queen Victoria Museum and Art Gallery, Launceston. Certain other conventions are noted in earlier contributions.

SYSTEMATIC ZOOLOGY

Family Regalecidae

Genus *REGALECUS* Ascanius, 1772

Regalecus Ascanius, 1772, p.5; type species *Ophidium glesne* Ascanius.

Regalecus glesne Ascanius, 1772

Regalecus glesne Ascanius, 1772, p.5.
Regalecus pacificus: Scott, 1982, p.189, pls 2-4 (local synonymy).

Recent Tasmanian examples

Two recent Tasmanian examples, one from Mersey Bluff, Devonport and one from Low Head have been reported and illustrated (Scott 1982). In September 1982 an example noted as about 3 m long (possibly with some distal imperfection) and 30 cm deep was found on the foreshore at Turners Beach, northwest coast. Ornamentation appeared to be confined to rounded or slightly longitudinally elongate spots ("black, thumbprint-like") and a few rather obscure smudges.

Observations on some Tasmanian fishes: Part XXIX

Suborder Trachiopteroidei

In the suborder Trachipteroidei [= Taeniosomi of Regan (1907) and Trachipteroidea + Veliferoidei in part of Berg (1940)] the Trachipteridae (three genera, *Trachipterus* Goüan, 1770, *Desmodema* Walters & Fitch, 1960, *Zu* Walters & Fitch, 1960) may be summarily distinguished from the other families thus: from Lophotidae (two recent genera, *Lophotes* Giorna, 1805, *Eumecichthys* Regan, 1907, and one extinct genus) in lacking an anal fin and an ink sac, and in not having the upper profile of the head sloping forward, overhanging the snout; from Regalecidae (two genera, *Regalecus* Ascanius, 1772 and *Agrostichthys* Phillipps, 1924) in having fewer vertebrae (69-102, cf. 143-ca. 170) and the lateral line plates smooth, not each with a spine. In the Handbook (Munro 1957) and in various texts by Whitley the Agrostichthyidae, instituted by Phillipps (1924), is treated as distinct from Regalecidae; Walters & Fitch (1960), while formally subsuming the former in the latter suggest "possibly it is at least subfamilially distinct"; in their provisional classification of living teleosts Greenwood *et al.* (1966), who customarily note alternative or partly equivalent family names in parentheses following the family name as recognized by them, have no entry (either in the index or the text) of Agrostichthidae, apparently overlooked. If the two taxa are accepted they may be distinguished by some trenchant characters of their type genera: thus in *Agrostichthys* gill rakers are few (8-10), the premaxilla continues forward in line with the frontal profile, the gastric caecum ends before the vent, teeth are present on lower jaw and on vomer, whereas in *Regalecus* gill rakers are numerous (40-58), the premaxilla is set about at a right angle to the frontal profile, the gastric caecum ends well behind the vent, teeth are absent. McCann (1953) states the lower jaw is hinged in *Regalecus*, fixed in *Agrostichthys*. It may be noted that in a detailed key to the four families by Whitley (1933) a couplet separating *Trachipterus* from *Regalecus* by the specification of the upper profile of the head as convex in the former, concave in the latter is incorrect in the first term (head shape in *Trachipterus* discussed below); while in a key to Regalecidae, *s.l.*, in Part XXVIII (Scott 1982, p.189) the description of the maxillary plate as "deeper than long" for *Regalecus pacificus* and as "longer than deep" for *Agrostichthys benhami* inadvertently transposes the specifications.

Over and above the ills to which Australian ichthyological systematics have traditionally been heir, such as early identification of local fish with Old World species(e.g., in the present context local species of *Trachipterus* Goüan, 1770 with *T. arcticus* Brünnich, 1778, *T. trachypterus* (Gmelin, 1789), *T. taenia* (Bloch & Schneider, 1801), *T. altivelis* Kner, 1859, followed by recognition of a distinct local species (followed, again in a number of instances, by a return to an original position) the regional taxonomy of trachipterids has had to contend with two unusual situations; first, the confusion of specific and even generic characters with those attributed, as in McCann (1953) to sex or, as in Phillipps (1944) and many authors, to age; secondly, a curious and quite exceptional disregard or misapprehension of generic limits. The second complication, which has resulted in some incorrect generic attributions that have continued even into some quite recent publications, is considered below.

The ventral profile of the trunk is entire (E) in *Trachipterus* and in *Desmodema*, but scalloped (S) in *Zu*. The main axis of the caudal fin (or, where the fin exhibits two lobes, at least the axis of the major (upper) lobe) is at a marked angle to the general anteroposterior axis of the fish (A) in *Trachipterus* and *Zu*, but continues in the general sense of that axis (C) in *Desmodema*. The three genera may therefore be symbolized by a two-letter code, thus: *Trachipterus* EA, *Desmodema* EC, *Zu* SA. While prior to the establishment of *Zu* Walters & Fitch, 1960 and *Desmodema* Walters & Fitch 1960 species now referable to one of these genera were naturally and inevitably accommodated in the only available and utilized genus *Trachipterus* Goüan, 1770, unfortunate and avoidable misidentification has occurred since their publication. In recent Australian literature *Trachipterus arawatae* Clarke, 1881, a genuine representative of that genus, and specifiable as EA, has been placed in *Desmodema*, which would require it to be EC. By synonymization of *Trachypterus* [*sic*] *jacksoniensis* [*sic*] *polystictus* Ogilby 1898 with *Trachipterus arawatae* and concomitant relegation of Clarke's species to *Desmodema*, while Ogilby's fish is nomenclaturally identified correctly as EC, Clarke's is nominated in error also as EC. Further, the use — e.g. in Whitley (1958, fig.1) — of the name *Desmodema arawatae* applied to a figure of a specimen of *Zu* sp. leads to this fish being treated by virtue of the first

binomen as being EC and by virtue of the second as EA, while actually being SA.

In the subjoined chronological selection of Australasian papers containing either primary records or important treatments of tracheriptids, together with several regional catalogues and works of a more popular nature, an attempt is made to set straight the regional nomenclatural record.

It should be noted that while the probable identifications here presented are in accord with the present climate of local taxonomic opinion they nevertheless make two implicit assumptions: firstly, that *Trachipterus arawatae* Clarke, 1881 (April) and *Regalaecus jacksonensis* Ramsay, 1881 (May) are conspecific, being based on young and adult individuals, respectively; secondly, that Clarke's New Zealand species is not identical with an earlier-described extra-Australasian species. The first (not unanimously accepted) remains at present unproved; the second would appear to be worthy of consideration following comparison, beyond the present logistic capacity of the writer, of appropriate material.

The local nomenclatural misapprehensions thus cleared up there yet remains the prior problem of the number and identity of the extra-Australasian species, a question that does not appear at present to have been satisfactorily resolved. Though probably best known from the Old World, dealfishes are distributed throughout the whole of the tropical and temperate zones, various species being described from different regions. Writing almost a hundred years ago, Günther (1887) enumerated nine species from the Mediterranean and the neighbouring Atlantic Ocean (noting that of one of these, *T taenia* Bloch — now usually credited to Schneider, 1801 — three others, *T. filicauda* Costa, *T. iris* (Walbaum, 1792) and *T. spinolae*, C & V [= Valenciennes, 1835] are, according to Emery (1879b) successive growth stages), one each from Cuba, and the East India Archipelago, and three from the Pacific. Something like two score of other nominal species have been described.

In a review of the dealfishes of the Mediterranean and northeast Atlantic Palmer (1961) recognized only two species, namely, *Trachipterus arcticus* (Brünnich, 1788), subsuming in it five nominal species (one of which, *T. bogmarus* Valenciennes, 1835, together with Brünnich's species itself, is cited in Australasian literature), and *Trachipterus trachypterus* (Gmelin, 1788), with seventeen synonyms, of which *T. iris* (Walbaum, 1792), *T. taenia* Schneider 1801, *T. spinolae* Valenciennes, 1835 and *T. falx* Valenciennes, 1835 have been applied to Australasian fish. Lacking access to extralimital material the present writer obviously is not in a position to arrive at an informed opinion as to whether or no these two forms are valid species. However, attention may perhaps appropriately be drawn to the fact that Palmer's key to them on p.339 includes no anatomical or meristic characteris, the three couplets of differentiae being wholly morphological, the first two relating to relative regional depths (a feature subject to variation with age) and the third to the straight or upcurved body axis in the posterior caudal regions in adults, a difference that is certainly present in young New Zealand individuals apparently identifiable as *T. arawatae*, cf. the figure of the type of that species and a photograph of a specimen referred by McCann (1953, fig.7) to *T. arcticus*: the caudal region is distinctly curved up in our two smallest examples. While the distinction of the Australian fish from those described earlier remains unestablished, the final elucidation of the taxonomic status of the latter clearly remains a matter of live interest. Palmer observes "*T. arawatae* Clarke (1880) [= 1881] from New Zealand may well be synonymous with the above" [*T. trachypterus*], and gives the distribution of Gmelin's species as Mediterranean, S. Africa, Central Pacific, New Zealand, with no southern hemisphere locality for Brünnich's. Elsewhere he makes incidental mention of "the Australian species, *T. jacksonensis*" (here treated as synonymic with *T. arawatae*). No comparative study has been carried out on *T. arawatae* with a number of other nominal species from widely ranging localities in the Pacific and Indian Oceans (or indeed from localities in the West Atlantic). A review of the main texts in the Australasian literature has been made and a tabular synopsis of published names and suggested emendations to these is subjoined.

Observations on some Tasmanian fishes: Part XXIX

MISIDENTIFICATIONS OF AUSTRALASIAN RIBBONFISHES IN THE LOCAL LITERATURE

A. *Trachipterus arawatae* Clarke 1881 (genus *Trachipterus* Goüan, 1770)

1. *Trachipterus altivilis* Kner, 1829: 1873, Hutton, F.W., *Trans. N.Z. Inst.*, 5, p.264, and 1876, *ibid.*, 8, p.219: 1883, Johnston, R.M., *Pap. Proc. R. Soc. Tasm.* (1882), p.123 (this specimen, providing the first record of a Tasmanian trachipterid, was noted as being in the Royal Society's Museum, Hobart (Now Tasmanian Museum): Mr A.P. Andrews, the institution's zoologist, informs me it is now not traceable): 1884, Macleay, W., *Proc. Linn. Soc. N.S.W.*, 9(1), p.43: Lord, C.E., 1923, *Pap. Proc. R. Soc. Tasm.* (1922), p.65, and 1927, *J. Pan-Pacific res. Inst.*, 2(4), p.13: 1924, Lord, C.E. & Scott, H.H., A SYNOPSIS OF THE VERTEBRATE ANIMALS OF TASMANIA, pp.9,47: 1927, Phillipps, W.J., *N.Z. Fisher. Bull.*, 1, p.26.

2. *Trachipterus*, sp. nov. Clarke, 1881: 1881, Clarke, F.E., *Trans. N.Z. Inst.*, 12, p.195, unnumbered fig.

3. *Regalecus jacksonensis* Ramsay, 1881: 1881, Ramsay, E.P., *Proc. Linn. Soc. N.S.W.*, 5, p.361, pl.20 [*Regalaecus*]: 1881, Macleay, W., *Proc. Linn. Soc. N.S.W.*, 6(1), p.55: 1927, Phillipps, W.J., *N.Z. Fisher. Bull.*, 1, p.27: 1929, McCulloch, A.R., *Aust. Mus. Mem.*, 5 (1), p.138.

4. *Trachipterus jacksonensis* (Ramsay, 1881): 1886, Ogilby, J.D., CATALOGUE OF FISHES OF NEW SOUTH WALES, p.43 [*jacksoniensis*]: 1906, Stead, D.G., FISHES OF AUSTRALIA ..., p.217, and 1913, *Proc. Linn. Soc. N.S.W.*, 37(3), p.492: 1916, Hamilton, H., *Trans. N.Z. Inst.*, 43, pp.370-382, fig. 1 (only): 1921, McCulloch, A.R., *Aust. Zool.*, 2(1), p.25, pl.11 [Part 2 of CHECK-LIST OF FISHES AND FISH-LIKE ANIMALS OF NEW SOUTH WALES: parts 1, 2 issued in book form, with different pagination, with additions by G.P. Whitley, 1922, 1927, 1934], and 1929, *Aust. Mus. Mem.*, 5(1), p.133: 1925, McCulloch, A.R. & Whitley, G.P., *Mem. Qld Mus.*, 8(2), p.170: 1926, Marshall, T.C., *Mem. Qld Mus.*, 8(2), p.123, and 1964, FISHES GREAT BARRIER REEF AND COASTAL WATERS OF QUEENSLAND, p.124, pl.29, fig.135, and 1966, TROPICAL FISHES GREAT BARRIER REEF, p.178, pl.29, fig.135: 1927, McCulloch, A.R., *in* Whitley, G.P., *Rec. Aust. Mus.*, 15(5), p.296, pl.25, fig.2: 1957, Munro, I.S.R., *Fisher. Newsl.* (now *Aust. Fisher.*), 16(4), p.64, sp.450, fig.450 [*jacksoniensis*] ("probably adult" of *T. arawatae*): 1978, Grant, E.M., GUIDE TO FISHES, p.134 [*jacksoniensis*].

5. *Trachipterus taenia* Bloch, 1801: 1886, M'Coy, F., PRODROMUS ZOOLOGY VICTORIA, 13, p.83, pl.122: Phillipps, W.J., *N.Z. Fisher. Bull.*, 1, p.26.

6. *Trachipterus spinolae* Cuvier, 1835: 1886, M'Coy, F., PRODROMUS ZOOLOGY VICTORIA, 13, p.84.

7. *Trachipterus falx* Valenciennes, 1835: 1886, M'Coy, F., PROD. ZOOL. VICTORIA, p.84.

8. *Trachipterus iris* Valenciennes, 1835 (*non* Walbaum, 1838): 1886, M'Coy, F., PROD. ZOOLOGY VICTORIA, p.84.

9. *Trachipterus trachypterus* (Gmelin, 1789): 1916, Hamilton, H., *Trans. N.Z. Inst.*, 43, pp.370-382, figs 3,4,5,6 (only): 1927, Phillipps, W.J., *N.Z. Fisher. Bull.*, 1, p.26.

10. *Trachipterus ishikawae* Jordan & Snyder, 1901: 1927, Phillipps, W.J., *N.Z. Fisher. Bull.*, 1, p.27.

11. *Trachypterus arcticus* (Brünnich, 1788): 1953, McCann, C., *Rec. Dom. Mus.*, 2(1), pp.1-17, figs 4,7 (only): 1960, Parrott, A.W., QUEER AND RARE FISHES OF NEW ZEALAND, fig.34, a,b.

12. *Desmodema arawatae* (Clarke, 1881): 1962, Whitley, G.P., MARINE FISHES OF AUSTRALIA, 1, p.65, one of two unnumbered figs, "Adult, after Whitley" [1927] , and 1964, *Proc. Linn. Soc. N.S.W.*, 89(1), p.41, and 1968, *Aust. Zool.*, 15(1), p.45, definitive entry only, not figure: 1974, Scott, T.D., C.J.M. Glover & R.V. Southcott, MARINE AND FRESHWATER FISHES OF SOUTH AUSTRALIA, p.99, unnumbered fig.: 1890, Vollard, J., ed.G.P. Whitley's HANDBOOK OF AUSTRALIAN FISHES, p.77, larger figure [after Clarke, 1881].

13. *Trachipterus iris* (Walbaum, 1838) (*non* Valenciennes, 1835): 1970, McKay, R.J., *Fisher. Bull. W. Aust.*, 9(5), p.7(?).

B. *Zu* sp., *cf. Zu cristatus* (Bonelli, 1820) (genus *Zu* Walters & Fitch, 1960)

1. *Trachipterus jacksonensis* (Ramsay, 1881): 1916, Hamilton, H., *Trans. N.Z. Inst.*, 43, pp.370-382, fig.2 (only): 1927, Phillipps, W.J., *N.Z. Fisher. Bull.*, 1, p.27, and *Rec. Dom.Mus.*, 1(2), p.120, pl.52 (color) [*jacksoniensis*].

Trachypterus arcticus (Brünnich, 1788): 1953, McCann, C., *Rec. Dom. Mus.*, 2(1), pp.1-17, figs 5,6 (only): 1960, Parrott, A.W., QUEER AND RARE FISHES OF NEW ZEALAND, p.100, fig.34, b (only).

3. *Desmodema arawatae* (Clarke, 1881): 1962, Whitley, G.P., MARINE FISHES OF AUSTRALIA, 1, p.65, one of two unnumbered figures, "young after Phillipps" [1914], and 1968, *Aust. Zool.*, 15(1), p.45, fig.1: 1980, Vollard, J., ed., G.P. Whitley's HANDBOOK OF AUSTRALIAN FISHES, p.77, smaller figure [after Phillipps, 1944].

C. *Desmodema polystícta* (Ogilby, 1898) (genus *Desmodema* Walters & Fitch, 1960)

1. *Trachipterus jacksoneniensis* [= *jacksonensis*] *polystictus*: Ogilby, D.J., *Proc. Linn. Soc. N.S.W.*, 22(3), p.646: McCulloch, A.R., 1929, *Aust. Mus. Mem.*, (5), 1, p.138: 1933, Whitley, G.P., *Rec. Aust. Mus.*, 19(1), p.72 (so listed, treated as synonym of *T. arawatae*).

2. *Trachipterus jacksonensis*: McCulloch, 1921, *Aust. Zool.*, 2(1), p.25 (Ogilby's specimen treated as young of this species).

The subjoined key to the three genera of Trachipteridae here recognized is based largely on the generic diagnoses by Walters & Fitch (1960) and, for the genera *Trachipterus* and *Zu*, on diagnoses of these by Palmer (1961) in a review of the dealfishes of the Mediterranean and northeast Atlantic.

KEY TO GENERA OF TRACHIPTERIDAE

1. Caudal fin with 1 lobe (5-8 weak rays); set in general sense of caudal peduncle, median rays subparallel to anteroposterior axis of fish. Number of pairs of lateral line plates per postanal vertebra > 2. Vertebrae 104-109. Scales non-imbricate, modified ctenoid (elliptical with 2 spinose ridges). Gastric caecum ends closer to vent than to pyloric valve. Color pattern uniform or polka dotted ..... *Desmodema*

   Caudal fin with 2 lobes (5-10 well developed rays); set at a pronounced angle to caudal peduncle, median rays forming an acute angle with caudad extension of anteroposterior axis of fish. Number of pairs of lateral line plates per post-anal vertebra < 2. Vertebrae 61-102. Scales absent or present; if present imbricate, cycloid. Gastric caecum ends closer to pyloric valve than to vent. Color pattern uniform; or with darker bars and/or blotches; or with several (usually 4) large, widely spaced, regularly positioned dark spots 2

2. Ventral profile of trunk strongly scalloped. Some rays in the dorsal crest and some in the pelvic fin bearing conspicuous dark (usually purplish or blackish) serially arranged bulbs or sacs (may be reduced to dark bars). Number of pairs of lateral line plates per postanal vertebra ≐ 1½. Vertebrae 62-69. Scales present, imbricate, cycloid, deciduous. Color pattern of dark subvertical bars and/or blotches ..... *Zu*

   Ventral profile of trunk not scalloped (may be some suggestion of scalloping in very small individuals). Dorsal and pelvic rays not bearing serially arranged bulbs or sacs. Number of pairs of lateral line plates per postanal vertebra ≐ 1. Vertebrae 69-102. Scales absent. Color pattern of several (usually 4) widely spaced, regularly positioned dark spots ..... *Trachipterus*

Observations are here presented on six Tasmanian examples of *Trachipterus arawatae* Clarke, 1801 and an account is given of a species of *Zu* Walters & Fitch, 1960, a genus here apparently for the first time recorded from Australia: local specimen provisionally determined as *Zu cristatus* (Bonelli, 1820).

Observations on some Tasmanian fishes: Part XXIX

Genus *TRACHIPTERUS* Goüan, 1770

Trachipterus Goüan, 1770, p.104. Type-species, *Cepola trachyptera* Gmelin, 1788. [Emended to *Trachypterus* by Agassiz (1845) and authors.]
Gymnogaster Brünnich, 1788, p.408. Type-species, *Gymnogaster arcticus* Brünnich.
Trachypterus Schneider, 1801, p.480. Type-species, *Trachipterus taenia*.
Bogmarus Schneider, 1801, p.518. Type-species, *Bogmarus islandicus* Schneider.
Argyctius Rafinesque, 1810, *Caratt. nuov. Gen.*, p.55. Type-species, *Argyctius quadrimaculatus* Rafinesque.
Cephalaspis Rafinesque, 1810, *Ind. Ittiol. Siciliana*, p.54. Type-species, *Cephalaspis octomaculatus* Rafinesque.
Epidesmus Ranzani, 1818, p.137. Type-species, *Epidesmus maculatus* Ranzani.
Regalaecus: Ramsay, 1881, p.631. *Non Regalecus* Ascanius, 1772.

Trachipterus arawatae Clarke, 1881
Figs 1-6

Trachipterus arawatae Clarke, 1881, p.195, unnumbered fig. Type locality: Arawata, New Zealand.
Regalaecus jacksonensis Ramsay, 1881, p.631, pl.20. Type locality: Manly Beach, Port Jackson, New South Wales.
?Cepola trachyptera Gmelin, 1788, p.1187. Type locality: Adriatic.

Synonymy

The two references above to Clarke and Ramsay are supplemented by additional information on synonymy in Australian and New Zealand authors set out earlier in the list of citations in the general remarks on the family; the possible relationship of northern and southern hemisphere species also has been discussed above.

Material

Eight examples in the collection of the Queen Victoria Museum and Art Gallery, Launceston, here listed in order of increasing length to origin of caudal fin: (a) estimated length to caudal origin (fish, as preserved, curved in posterior half) 100, oblique length of caudal 48, T.A. Cook's Beach, Coles Bay, east coast, collected 25 January 1971, G.F. O'Brien, Q.V.M. Reg. No. 1971/5/3; (b) length without caudal 212, oblique length of caudal 85, Albatross Island, Bass Strait, collected 26 January 1973, Q.V.M. Reg. No. 1973/5/36; (c) length without caudal, mouth protracted 310, mouth not protracted ca. 296, Boat Harbour, northwest coast, R. Laughlin, Q.V.M. Reg. No. 1957/5/4; (d) length without caudal 444, oblique length of caudal 112, same history as (c); (e) length without caudal 508, Smithton, northwest coast, B.H. Wragge, Q.V.M. Reg. No. 1945.13; (f) length to caudal origin 555, oblique length of caudal 170, caught alive at Smithton, northwest coast, H. Smarden, Q.V.M. Reg. No. 1942.1; (g) length without caudal 560, oblique length of caudal 133, south end of Three Hummock Island, Bass Strait, collected December 1969, one of two found dead on beach, Alliston, Q.V.M. Reg. No. 1973/5/4; (h) badly damaged, much of head missing, estimated length to caudal base 630, oblique length of caudal 100, Marthia Lavinia Beach, King Island, Bass Strait, collected 12 January 1969, Q.V.M. Reg. No. 1969/5/4 (last specimen considered only in relation to coloration).

Dimensions

A set of measurements is given in table 1, all entries other than length to caudal origin (standard length, *Ls*) being recorded as millesimals of *Ls*; this being the first detailed schedule of dimensions reported for the local species.

Proportions

It has been known for more than a century that *Trachipterus* undergoes noticeable morphological changes during ontogeny. Working with *T. taenia* Emery (1879a,b) reported the fin rays begin to grow in the young when it is about 6 mm long, continue to lengthen till it is about four times that size, the relative size thereafter decreasing; however, Lo Bianco (1908) has since shown Emery's study pointed to the occurrence of a more profound series of morphological changes than actually occurs, his material having represented a mixture of species, including larval flounders of the genus *Ammopleurops*. It remains clear

that the course of postlarval development is characterized by a decrease in the relative magnitude of (a) the height of the nuchal crest, thus in fish 64 mm, 260 mm and 1400 mm the length of the longest crest ray is approximately 1.8, 0.3, .0.1 length of head, or approximately 2.4, 22, 80 in *Ls* (measurements of Clarke, figures of M'Coy, Ramsay — the last of the type of *Regalecus jacksonensis*); (b) the maximum height of the second dorsal, approximately 0.7, 0.5, 0.2 length of head, or approximately 6, 10, 40 in *Ls*; (c) the length of the ventral, 3.4, 0.6, ? (tubercle only) length of head, or 1.3, 6, ? in *Ls*. In our material only one first ray of the crest is intact, specimen (e); this is 0.64 head, 13.7 in *Ls*: the other intact lengthy element of the crest is a second ray, specimen (g), which is 1.28 head, 6.7 in *Ls*. The longest ray of the second dorsal (so far as this can be determined, some fins being incomplete) is 0.76-0.91, $\bar{x}$ 0.84 ± 0.019 length of head, or 5.0-11.6, $\bar{x}$ 8.37 ± 0.845 in *Ls*. The ratio ray-in-*Ls*, but not the ratio ray-times-head, yields a significant correlation with *Ls*, r 0.927 (z 1.640). Longest intact ventral ray (not necessarily largest, preservation being poor) in the Tasmanian specimens is 0.76-2.14, $\bar{x}$ 1.89 ± 0.17 length of head or 2.13-95, $\bar{x}$ 6.76 ± 1.12 in *Ls*: both ratios exhibit significant correlation with *Ls*, r being -0.843 (z -1.232), 0.961 (z 1.868).

Some other proportions conventionally recorded are: head in *Ls* 4.5-8.8, $\bar{x}$ 6.99 ± 0.650, length to vent in *Ls* 1.4-2.1, $\bar{x}$ 1.81 ± 106, maximum depth in *Ls*, 3.9-6.3, $\bar{x}$ 4.78 ± 0.524, depth at vent in *Ls* 5.6-8.5, $\bar{x}$ 7.68 ± 0.444, mean depth in *Ls* (mean of 10 equidistant measurements) 6.2-10.7, $\bar{x}$ 8.83 ± 0.725, eye in head 3.2-3.9, $\bar{x}$ 3.58 ± 0.095, snout in head 2.8-3.9, $\bar{x}$ 3.25 ± 0.169, interorbital in eye 1.2-3.1, $\bar{x}$ 1.65 ± 0.248.

Relative growth

In addition to the marked changes with growth of the lengths of the fin rays, size-related variations are exhibited by a number of other features. Each of the 7 dimensions for which tabulated data are set out below presents a decrease in relative value (magnitude expressed as millesimals of standard length) with increasing overall size. The recorded extremes of the ranges are those for the smallest and the largest fish (the entry in parentheses being that of a value smaller than that for the largest specimen: one such value is found in each entry, with two, equal, in depth at vent).

Length of head 220.0-116.1 (114.1), r -0.989 (z -2.599).
Length to vent 640.0-485.7 (473.9), r -0.964 (z -2.000).
Maximum depth 260.0-190.9 (153.2), r -0.693 (z -2.143).
Mean depth 162.7-93.2 (91.7), r -0.902 (z -1.483).
Depth at vent 180.0-128.6 (117.1), r -0.902 (z -1.483).
Length to pectoral origin 200.0-112.5 (106.5), r -0.972 (z -2.139).
Length to ventral origin 250.0-141.1 (120.7), r -0.964 (z -2.000).

A number of other negative correlations of the relative length of a dimension with *Ls* are noted below.

The situation in respect of the systematic variation with age (overall size) of the longitudinal extension of the three primary regions of the fish, head, trunk and tail, is an interesting one. Graphs of the *TLs* lengths of these regions plotted against *Ls* are presented in fig. 1. This shows that as overall length increases through the range of the present sample (100-560 mm), the relative length of the head (*TLs*) systematically decreases (in largest individual 53% of that in smallest), as also does that of the trunk (in largest 88% of that of smallest), while, with commensurate compensation, relative length of tail increases (in largest 143% of that of smallest). The relation is in each case effectively linear (t 14.911***, 3.948*, 11.704***); slopes -0.223, -0.139, 0.362; intercepts 236.7, 451.9, 311.4. While some variation during ontogeny in the relative lengths of these regions is not unusual, so large an increase in magnitude of one as here encountered (43%) is to be regarded as exceptional.

The relative forward migration of the vent from a point at 0.62 of the standard length to a point at 0.49 is of interest in view of the taxonomic importance attached to its locus in the Trachipteroidei, this being in the anterior third of the body in Regalecidae, near the end of the body in Lophotidae, while in Trachipteridae its position is specified by Walters & Fitch as "in the first half of the body or slightly behind mid-body" — the general emphasis of "in" and "slightly" perhaps suggesting examination of a sample of specimens of greater overall size.

TABLE 1

TRACHIPTERUS ARALATAE CLARKE, 1881. DIMENSIONS OF 7 TASMANIAN EXAMPLES.
First line in mm, all other entries as millesimals of standard length.

Dimension	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Standard length mm	100	212	296	444	508	555	560
Length of caudal	480	401	-	352	-	306	238
Head	220	182	172	140	114	117	116
Snout	65	47	54	50	39	31	41
Eye	65	57	47	36	30	34	32
Interorbital	210	35	33	27	26	24	21
Length to vent (middle)	640	613	595	547	498	474	486
Length to first dorsal origin	125	68	135	122	65	49	77
Length to first dorsal termination	155	92	149	126	77	58	88
Length to second dorsal origin	180	97	159	155	80	67	91
Length of first ray of first dorsal	-	-	-	-	73	-	-
Length of longest preserved ray of first dorsal	-	-	-	-	73(1st)	-	148(2nd)
Length of dorsal ray over first superior spot	170	-	51	81	81	67	75
Length of dorsal ray over second superior spot	210	121	57	113	(no spot)	85	102
Length of dorsal ray over third superior spot	150	-	78	84	73	76	82
Length of longest dorsal ray preserved intact	ca 200	149	78	119	106	101	102
Length to pectoral origin	200	172	176	140	108	166	113
Length of pectoral base (oblique)	25	189	203	15.8	15.7	11.7	12.5
Length of pectoral	100	78	67.6	51.8	39.4	45.0	42.9
Length to ventral origin	250	191	193	155	146	121	141
Length to first superior spot (middle)	360	241	291	225	181	166	205
Length to ventral spot (middle)	350	283	277	243	206	198	205
Length to second superior spot (middle)	600	462	541	428	374	403	393
Length to third superior spot (middle)	780	651	710	-	630	605	598
Depth at front of eye	180	156	135	99	93	90	98
Depth at back of eye	250	231	172	137	138	144	132
Depth at operculum	250	250	196	160	173	159	163
Depth at vent	180	156	142	117	134	123	129
Maximum depth			2	162			
10 equidistant measurements of depth	290 285	250 248	203 209	162 160	167 167	159 159	170 170
	220 195	226 203	196 189	149 142	161 150	153 149	161 138
	180 160	170 146	176 152	135 104	134 100	119 89	116 79
	130 90	90 42	132 84	72 36	63 31	58 31	48 25
	55 16	30 17	27 12	20 9	18 8	16 5	16 11
Distance of lateral line from ventral profile at its origin	175	146	109	101	91	113	96
Distance of lateral line from ventral profile at opercular border	170	146	125	90	91	90	90
Distance of lateral line from ventral profile at vent	62	47	68	110	73	67	32
Length of gill filaments on lower anterior arch	55	52	34	26	14	19	13
Length (oblique) of maxillary plate	81	76	61	45	45	41	46
Width (oblique) of maxillary plate							
Length of premaxilla, including process	50	47	34	23	26	26	30
Height of pterygiophore at operculum	56	47	50	32	35	29	32
Height of pterygiophore at vent	79	57	66	45	45	40	50
Height of pterygiophore, maximum	80	66	78	56	57	45	55

PLATE 1 - *Zu* sp., cf. *Zu cristatus* (Bonelli, 1820). Specimen collected by Mrs H. Reeman at East Inlet, Stanley, NW coast, Tasmania, July 1972, standard length 405 mm; length of head 55 mm.

PLATE 2 - Enlargement of head of specimen shown in plate 1.

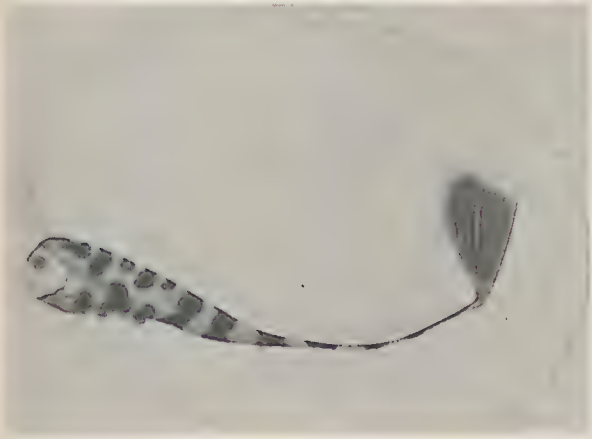

PLATE 3 - *Zu* sp., cf. *Zu cristatus* (Bonelli, 1820). Reproduction of color illustration in Phillipps (1924, pl.52) of a ribbonfish from French Pass, New Zealand, determined as *Trachipterus jacksoniensis* Ramsay, 1881.

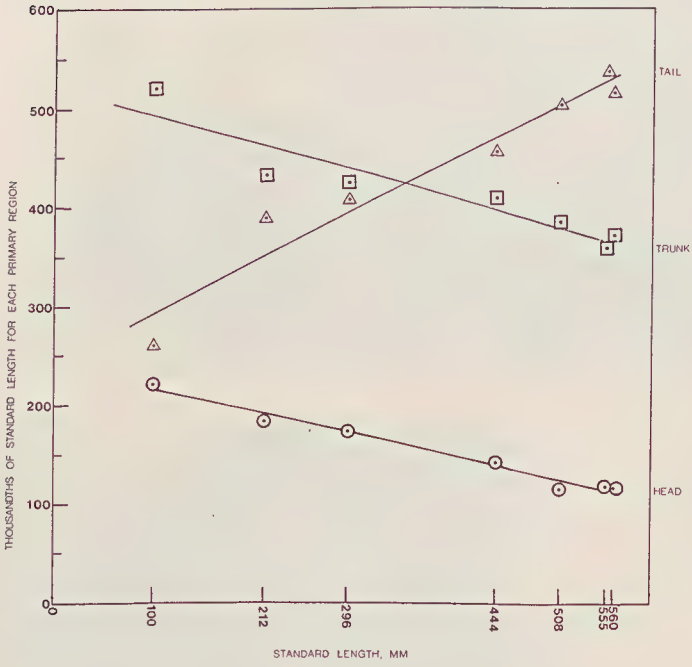

FIG. 1 - *Trachipterus arawatae* Clarke, 1881. Relative length of head, trunk, tail in 7 specimens of standard length 100-560 mm.

General description

Australian accounts of trachipterids have in general been based on a single individual. While noting he had three Victorian examples of *Trachypterus taenia* (Bloch) 419 mm, 260 mm and 66 mm in length before him, M'Coy (1886) chose to give an account, illustrated by his main figure (fig. 1 a-e), of the "average" specimen, though providing also an overall representation, natural size (fig. 2) of the smallest fish, specified in the legend as "probably of the same species", but in the text (p.85) provisionally identified as "Cuvier's" *T. spinolae*: the fish figured are *T. arawatae*. A consideration in a paper by McCann (1953) of four New Zealand trachipterids, in which there is made an assumption of striking sexual dimorphism, leading to the identification of two (figs 4, 7) as females (adult, young, respectively) of *Trachypterus arcticus* Brünnich, and two (figs 5, 6) as adult males of that species served only to confuse the general situation. Of the two fish identified as females of Brünnich's European species one (fig. 7) is certainly, one, without obvious markings, (fig. 4) is probably identifiable as *T. arawatae*, while both the fish identified as males of that form are generically distinct, being referable to the (subsequently described) genus *Zu*. (Some further relegations to *Trachipterus* of specimens properly assignable to *Zu* — resulting in continued confusion — are cited in the tabulated list of Australasian trachipterid determinations set out above.)

The present examination of a series of 7 examples, 100-560 mm in standard length, with some incidental reference to an eighth, damaged individual, ca. 730 in standard length, has made possible the recognition of some size-related characters not previously noted. Features considered in the three main Australian accounts of ribbonfish of the family Trachipteridae — *T. jacksoniensis polystictus (= Desmodema polysticta)* by Ogilby (1881), length to base of caudal ca. 140 mm; *T. taenia* (= *T. arawatae*) by M'Coy, as above; *T. jacksonensis (= T. arawatae)* by McCulloch (in Whitley 1927), length "to tip of tail (incomplete) 1925 mm" — are incorporated in the present description, together with some additional items. The description is based primarily on the well-preserved largest example, (g), *Ls* 560 mm, with variations exhibited by the other examples noticed as appropriate.

(a) General form. In the following specification of general form in the terminology of Gregory (1928) the entry in parentheses records the magnitude of the relevant ratio as exhibited by specimen (g). Dolichosomatic (0.18), gasterion preapical (0.89), apex anterior (0.16), gasterion anterior (0.14), dolichonotic (0.097), dolichogastric (0.086), leptopygidial (0.059), opisthion posturamic (0.018). It may be observed in passing that of the three categories recognized in Gregory's analysis of the proportion of the total posterior vertical (at caudal peduncle) to total anterior vertical (total body depth) — leptopygidial < ¼, nomopygidial ¼–½, macropygidial > ½ — the width of applicability of the first is such as to afford no distinction between a fish, e.g. a scorpid or typical chaetodontid with a tolerably slender caudal peduncle, and a form such as the present in which the peducnle is extremely attenuate. The anterior or entering angle between the anterodorsal and anteroventral slopes at the prosthion (most anterior point) comprises an anterodorsal angle of 31° and an anteroventral angle of 31° (indicative of a somehwat unusual symmetry; note, however, that the gasterion is slightly in advance of the apex — by 1.8% of standard length — hence the general angle of the anterior ventral contour is slightly steeper than that of the anterior dorsal contour); the posterior angle between the posterodorsal and posteroventral slopes at the uranion (point of intersection of horizontal axis and posterior border of caudal) has dorsal and ventral components of approximately 7° and 6°, respectively; the dorsal angle between the anterodorsal and posterodorsal slopes at the apex (highest point) is 143°, with the corresponding ventral angle at the gasterion (lowest point) virtually equal at 144°.

While at a glance the body shape has the appearance of being a tolerably uniform pennon, examination of an outline tracing reveals both dorsal and ventral borders undergo some changes of direction, giving rise behind the apex (at 16% of *Ls*) and behind the gasterion (at 19% of *Ls*) to three readily recognizable more or less linear segments. In the tracing of specimen (g) these account, in succession caudad, for 32% of *Ls* at an angle to the general anteroposterior axis of the fish of about 3°48', for another 32% at about 11°18'; for about 20% 2°36': for the ventral postcephalic outline the three segments are as follows, for about 27% of the length 2°40', for about 36% 8°30', for about 23% 5°0'.

As noted earlier in the section on differential growth maximum depth, depth at vent and mean depth calculated from the 10 equidistant measurements recorded in table 1 all exhibit negative correlation with *Ls* at P 0.01 or better. When the sample means of total depth (sum of these 10 measurements) are plotted at 10 equal intervals they yield the sigmoid curve shown in fig. 2, where the depths are given as *TLs*. The depth-number correlation is r -0.985 (z -2.442), equivalent to t 15.981***, the curve being adequately specified (R 0.998) by the 4° polynomial $D = 206.1 - 6.22N + 2.6162N^2 - 1.0733N^3 + 0.0068328N^4$. The upwardly convex element, with the greater amplitude, is anterior: a line joining the first and last points intercepts the curve, marking approximately the point of inflexion, about midway between the 7th and 8th deciles (for the means of the subsamples comprising the three smaller individuals and the four larger individuals the interceptions occur at about the 6th and 7th deciles, respectively).

From table 1 it is evident that first and second of the 10 successive measurements of depth are very closely similar, the sample means being equal in three individuals, with the first exceeding the second in three cases and being less than it in one case; with overall means of 200.1 and 199.4 they can reasonably be equated (t = 0.073). Using the mean of the first and second and eight other depths, two rectified formulations of the curve yielding satisfactory fits can be found. When the logarithmic values of these are plotted against their serial numbers, proceeding cephalad, the two-segment graph, with point of inflexion at the 5th decile, shown in fig. 2 is obtained. The parameters of the best straight lines are: slope 1.4872, 0.7401; intercept 1.0107, 0.7401; r 0.9972 (z 3.288), 0.9987 (z 3.669). For an alternative approach the virtual identity of the first and second depths suggests examination as a possible abscissal scale of the Fibonacci series, in which the first two terms are identical, 1, 1; the next eight terms (each the sum of the two immediately preceding) being 2, 3, 5, 8, 13, 21, 34, 55. With the logarithmic values of the *TLs* mean depths of the sample (first two averaged) plotted against the relevant nine abscissae the resultant graph, shown in fig. 3, has the form of two effectively linear segments; parameters for the two best straight lines: slope -0.03022, -0.01881; intercept 2.3194, 2.0712; r -0.9997 (z 4.402), -0.9990 (z 4.951). The first of the above two rectifications has the

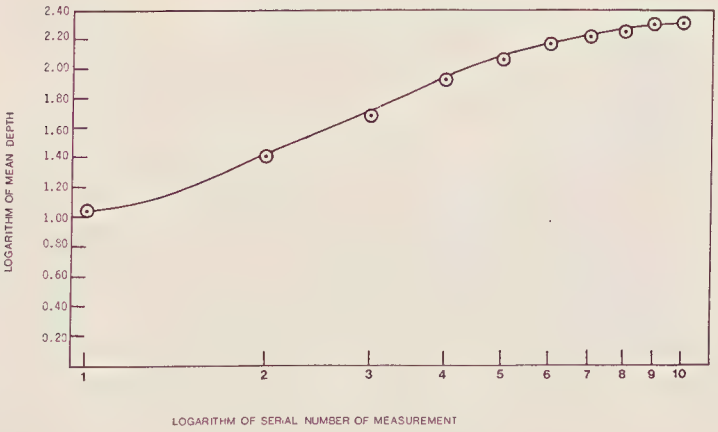

FIG. 2 - *Trachipterus arawatae* Clarke, 1881. Logarithms of means for 7 specimens of standard length 100-560 mm of 10 measurements of depth at equal intervals along anteroposterior axis of fish on logarithms of serial numbers of measurements, counting cephalad.

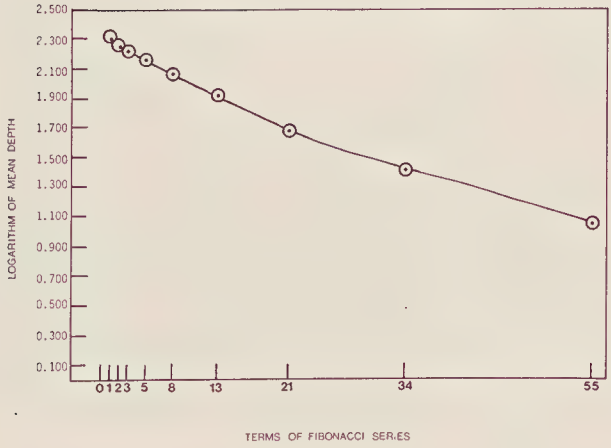

FIG. 3 - *Trachipterus arawatae* Clarke, 1881. Logarithms of means for 7 specimens of standard length 100-560 mm of 10 measurements of depth at equal intervals along anteroposterior axis of fish on the Fibonacci series: mean of measurements 1 and 2 on mean of first 2 items of series (1), measurements 3-10 on terms 1-10 of series (2, 3, 5, 8, 13, 21, 34, 55).

higher t value for the posterior depths (26.807, d.f. 4, against 22.103, d.f. 1), the lower for the anterior depths (30.293, d.f. 2, against 84.893, d.f. 5). The occurrence in each graph of a point of inflexion is not unexpected in view of the earlier noted change in the length growth gradient from negative in head and trunk to strongly positive in tail.

In a further investigation of intrasample variation, regression equations have been calculated for each of the 10 *TLs* depth measurements of the seven individuals; r ranges from -0.817 to -0.967, with a mean of -0.917 (equivalent to t 5.093; d.f. 8). The result of plotting the 10 slopes of the regressions against the serial numbers 1-10 is the evenly flowing curve shown in fig. 4.

The taeniate nature of *Trachipterus* is made evident by the fact that the maximum thickness ranges from 38 and 47 thousandths of standard length in the two smaller specimens

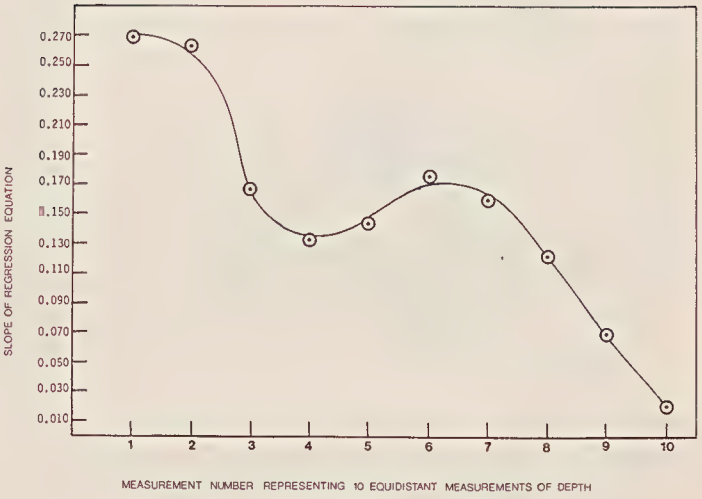

FIG. 4 - *Trachipterus arawatae* Clarke, 1881. Slope of regression equation of relative depth (depth as millesimals of standard depth) on standard length; 10 depths at equal intervals along antero-posterior axis of fish, each for 7 specimens of standard length 100-560 mm.

down to 19 among the others ($\bar{x}$ 27.6 ± 0.399). Measurements of thickness were made immediately in advance of the eye, at the thickest part of the operculum, at the level of the vent and just in advance of the caudal origin immediately preceding the small terminal subglobular swelling. The mean value of these four dimensions, in *TLs*, is 12.5-27.4, $\bar{x}$ 17.81 ± 2.205, the series exhibiting a significant negative correlation with size of fish, *Ls*; r -0.864 (z 1.053). It may be presumed that with thickness, as with depth, a certain minimum relative magnitude is a prerequisite for the general functioning of the fish, but with growth the proportionate values of these features may be progressively diminished.

(b) Size of head. Expressed as millesimals of length to caudal origin the length of the head ranges from 220 in the smallest down to 116 in the largest. For absolute length of head and of fish the correlation is r -0.958, for relative length of head (as *TLs*) and measured length of fish r -0.989; the slopes of the regression equations (significant at t 7.457, 14.931) are 0.0851 and -0.223, respectively, the intercepts 19.1 and 236.7. The application of these formulations to specimens noted in the literature yields very satisfactory results with examples not exceeding in size those of our material, but does not extend to examples with length of the order of two metres. Thus head length as *TLs*, as calculated from Clarke's measurement of the type-specimen is 209.5 (as estimated by extrapolation of the relevant regression equation above 222.4); for M'Coy's larger individual (data for others inadequate) it is 178.9 (cf. 178.7). On the other hand, use of approximate dimensions derivable from McCulloch's account of his large *T. jacksonensis*, length 1 925 mm+, would yield a negative value for head length, zero length being reached at a fish length of 1 000-1 100 mm.

(c) Shape of head (figs 5 and 6). Early misconceptions regarding the shape of the head (largely arising from failure to distinguish between the very different profiles, particularly the dorsal profiles presented with the mouth parts protruded and with these retracted) has continued and found their way into family keys and synoptic surveys. Thus in a detailed key to the ribbonfishes of Australia and New Zealand by Whitley (1933) - based on a key in a paper by Phillipps (1924) instituting the family Agrostichthyidae - in which each of the four families is regarded by being represented by a single species, the upper profile of the head is specified thus: Trachipteridae "convex", Regalecidae "markedly concave", Agrostichthyidae "convex", Lophotidae "sloping obliquely forward, overhanging the snout" (this is appropriate and needs no comment). In the Handbook (Munro, 1957) the entries for the three families in order as above are "concave" for *T. arawatae* and "convex"

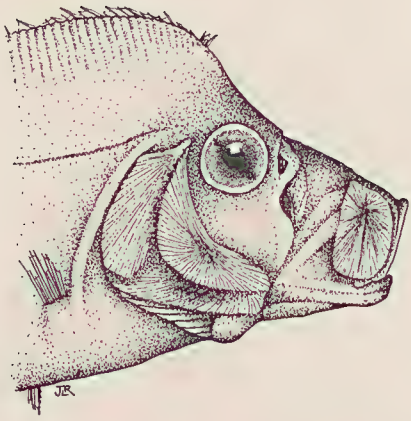

FIG. 5 - *Trachipterus arawatae* Clarke, 1881. Head, lateral view of a specimen collected by Mr B. Laughlin at Boat Harbour, northwest coast, Tasmania, 1957, standard length 444 mm; length of head 62 mm.

FIG. 6 - *Trachipterus arawatae* Clarke, 1881. Frontal view of a specimen collected by Mr D. Milledge at Albatross Island, Bass Strait, 26 January 1973, standard length 212 mm.

for *T. jacksonensis* [rendered *jacksoniensis*], *"concave"*, *"convex"*. Again, in a recent key by the writer in Part XXVIII (1982) to Regalecidae, treated as embracing both *Regalecus* and *Agrostichthys*, the former genus is noted as having the profile concave, the latter convex. With the mouth of the fish not extruded, the correct indication for Australasian species of the anterior head profile, or at least of the greater part of it with the possible exception of a small section antecedent to its becoming the dorsal profile, would appear to be as follows: Trachipteridae, *T. arawatae*, specimens to about 1 m in length linear, oblique, at an angle of round about 50° (in a figure by McCulloch (in Whitley 1927) of a presumed adult, about 2 m in length, identified as *T. jacksonensis*, barely convex), Regalecidae (as represented by type-genus), Agrostichthyidae (as represented by type-genus) virtually linear at an overall angle of approximately 60°, gently rounded.

In the present material the long, movable premaxillary process, fitting, above the level of about the middle of the pupil, into a fleshy sheath, extends in a straight line obliquely from the upper lip, located close to the level of the inferior border of the orbit, for about two-thirds of the distance to the base of the first dorsal ray, terminating vertically above the middle of the eye (in specimens (e), (b) above 0.9, 0.3 eye), directly distant from it by approximately half an eye diameter. The remaining, soft portion of the anterior cephalic profile is straight, or very nearly so, extending either in the same general line as the longer rigid premaxillary segment or inclined a trifle forward, the angle showing some individual variation. The inferior profile of the head is overall close to linear or somewhat sinuous, with some tendency towards a local convexity posteriorly; in general its length from lower lip to margin of branchiostegal membrane and its degree of slope from anteroposterior axis of fish more or less parallel those of the rigid segment of the superior profile. The lateral surface of the head is close to flat, the two sides being largely parallel, but tending to diverge somewhat posteriorly the maximum thickness being subequal to an eye diameter.

Comparison of our material with some published illustrations of this species reveal certain differences as follows. The figure of the type specimen (Clarke 1881) shows the profile between mouth and dorsal origin as comprising three subequal segments, the upper slightly concave or sinuous, the others concave, these latter extending to above the level

of the eye and together representing the region of the premaxillary processes, which actually is linear. The significance in this figure of the pair of closely apposed parallel lines between mouth and dorsal origin is unclear; does it perhaps represent a cubist notation intended to draw attention to the plate described further below, that constitutes such a conspicuous feature of the flat frontal aspect of this region of the head? McCann's (1953) fig. 7 (fish identified as *T. areticus*) shows a head of characteristic form, but in his fig. 4 (similarly identified) the (slightly convex) frontal slope is set at a lower angle. (The identity of the wholly unornamented fish illustrated by this photograph presents something of a problem, a curious feature being the location of the origin of the dorsal fin, as far as can be judged well behind the head, instead of over the oreoperculum or hind part of the eye. Unfortunately the size is not reported, though the photograph includes an unmarked rule: if this is 1 foot long (305 mm), the standard length of the specimen would be about 1.7 m, a size that would ally it with *T. jacksonensis*, here regarded as *T. arawatae*). In the illustrations of *T. jacksonensis* by Ogilby and by McCulloch the frontal profile is gently convex, being set at a lesser angle than in our material. In both figures by M'Coy the mouth parts are protracted, the contour between upper lip and dorsal insertion thus coming to consist of two subequal virtually linear moities set at an angle of approximately 160° (larger individual) and 150°, resulting in the profile coming to be reported as concave.

(d) General features of head. In specimens with the mouth not produced the maxillary extends from the anterior border to the middle of the pupil. The large tolerably rigid flat membranous plate is subovate, widest in its hind two-thirds, margins in anterior one-third or so somewhat concave or sinuous and converging to a blunt point; length, measured obliquely between tips, 1.5-2.0, $\bar{x}$ 1.70 ± 1.003, width, measured obliquely, 2.4-3.1, $\bar{x}$ 2.71 ± 0.0890 in head. From a point near its anterior one-fifth there radiate backwards right to margin about a score of well developed striae, longer ones mostly bifid distally, some shorter ones, particularly near upper anterior border, somewhat ramose; plate articulated anteriorly upon exposed processes of quadrate and hyomandibular (as noted by McCulloch for his specimen of *T. jacksonensis*, movable upon these). When mouth is retracted major axis of plate is at about 45°, but as mouth is protruded it swings round to end up by being vertical. Attached to, and partly overlapping, anterior four-fifths of its posterior border is a tumid fleshy structure, its anterior half little more than a ridge, rest widening out into rounded subtriangular flap, its greatest width about one-third that of plate and subequal to its distance from orbit; length (chord) about 2.5 width, about 1.5 in head. Below posterior two-thirds of eye a large naked area, filling more or less triangular space between preoperculum and maxillary plate. The preoperculum is crescentic, the strongly concave anterior border extending from upper third of posterior border of orbit to below about middle of eye, more than an eye diameter below it and about one-third as far from ventral profile; hind border evenly convex; anterior border with a narrow smooth raised rim; rest of surface with about a score of striae, radiating from a point near middle of anterior border; length (chord) about 2.5 times width, about 1.5 in head. Originating behind preoperculum at level of inferior orbital border and sloping down and back at about 45° for a distance subequal to diameter of orbit border or interoperculum continues more or less parallel with preoperculum, ending below tip of that plate; strong striae radiating from point somewhat beneath middle of anterior border; length four times width, a little less than length of preoperculum, subequal to distance of plate from pupil. Operculum extending down to level of mouth, smaller than is usual in most fish as result of extensive development of interoperculum; free border originating at level of superior orbital border, tracing concave arc down and back to small rounded or squared-off process, usually with several denticulations, near level of inferior orbital border, continuing down, somewhat concave, for about half as far to meet small downwardly and forwardly striated suboperculum; oblique down-back striae from point near upper extremity, a few short ridges above this point: both plates with outer marginal unstriated gelatinous strip. All plates of the complex thin, fragile.

Upper lip a narrow band of equal height throughout or a little deeper anteriorly. Viewed from in front region above lip an almost flat trapezoidal plate covered with transversely wrinkled integument, width about an eye diameter subequal to height, upper border about level with upper border of pupil; on either side curve down the ends of the premaxillary processes, their gradually converging upper portions rising to half an eye diameter

or more above eye; processes received into a groove flanked by an elevated triangle formed by the sharp edges of the frontals, separate throughout their extent, convergent upward; floor of groove containing mesethmoid and orbitosphenoid (fig. 6). The *TLs* height of the plate is 28-60, $\bar{x}$ 37.4 ± 4.26, of plate plus free premaxillary processes 84-121, $\bar{x}$ 105.3 ± 6.86; both magnitudes negatively correlated with *Ls*, *r* -0.940 (*z* -1.737), -0.890 (*z* -1.432). With mouth protruded three subtriangular naked areas develop; largest very thin, translucent, approaching transparent, bounded above by premaxillary process, in front by upper jaw, behind by subocular pre-preopercular fleshy area present with mouth shut; next largest semitranslucent, bounded by upper and lower jaws and in front by erect maxillary plate; smallest bounded above by mandible, behind by operculum and branchiostegal apparatus, below forming ventral profile, here mostly translucent but thickened, opaque along most of free margin.

Mandible widening posteriorly to one-fourth of its length, which is subequal to distance of slightly expanded tip from pupil, longitudinally ridged and grooved, with some irregular ridges and rugosities particularly in its hinder half. Upper jaw somewhat less stout than lower, slightly upwardly concave, of subequal depth throughout, longitudinally ridged. A palatal foramen in anterior third of mouth. In lower jaw on each mandible a row of 3-4 teeth of variable size, largest twice smallest, in general larger than teeth of upper jaw, subconical or somewhat flattened, straight, acute, directed upward and slightly backward, interval less than height, innermost almost on symphysis; on each side 1-2 minute behind primary row. Along the inner border of each premaxilla a linear row of elongate straight slender pointed teeth, directed downward and markedly inward, intervals between them subequal, about half interval between the two sets. No vomerine or palatine teeth were detected. No note on dentition was provided for the type specimen of *T. arawatae*; of the type of *Regalaecus jacksonensis* Ramsay noted" four teeth on either side of the lower jaw, conical, not strong; and five teeth on each side of the upper jaw", in general agreement with the situation as found in our material; however, in his account of a large ribbonfish determined as Ransay's species McCulloch reports two mandibular rows, as here, but adds three acute teeth in a row on a median process of the vomer and one or two on the palatine. In his generic diagnosis of *Trachipterus* Palmer (1961) observes, "Recurved pointed teeth in both jaws, 6 to 12 in the upper, 6 to 10 in the lower. Vomer with 1 to 2 median teeth. Palatine teeth, if present, feeble".

Nostril single, small circular pore set in shallow oblique subelliptical depression at 9 o'clock relative to eye (left side viewed), distance from eye subequal to that from upper edge of rhomboidal supralabial plate (in advance of which mouth extends when protracted), subequal to internarial interval. Gills 4, slit behind last. Relative length of gill lamellae in smallest specimen in sample much greater than (about four times) that in largest, i.e. absolute dimensions of same order of magnitude: *TLs* length of longest lamella near middle of anterior branchial arch 13-55, $\bar{x}$ 30.4 ± 7.70. An areal relation would seem to be involved: it is found by trial that with *TLs* lamellar length denoted by *G* and standard length by *Ls* there obtains a statistically significant relation, $G^{-2} = -0.00827 + 8.48$, with *r* -0.965 (*z* -2.007), equivalent to *t* 8.172***. Branchiostegals 6, the membranes not broadly connected across the isthmus. Gill rakers on upper limb of anterior arch usually 4, sometimes 5, small slender and pointed or tolerably stout and blunt (variation may occur on two sides of same fish), generally with a few often broad-based small setiform spines; on lower arch 9-10, modally 9, uppermost longest, up to 6-8 times lowermost, size decreasing regularly, typically 1st elongate slender pointed, 2nd less pointed, 3rd to 5th or 6th, sometimes to last spatulate, tending to become increasingly recurved towards inferior end of series, most with some spines, on one edge or both, commonly best developed proximally but exhibiting considerable variation in location, also in number, size and form.

(e) Lateral line. Lateral line originating at, or slightly below, level of upper orbital border, less than an eye diameter behind eye, sloping down briefly subparallel to dorsal profile, thereafter from above opercular border running back in virtually a straight line, evenly approaching ventral border, almost reaching it round about a head length from caudal origin, thereafter being almost parallel with it. Each lateral line scale bears a spine, small inconspicuous but readily detectable by touch in front, becoming progressively larger caudad, the last 8-12 large spines, height about half interval, projecting beyond

ventral profile; plates smaller anteriorly, 8-10 in an eye diameter at origin of line, 6-7 near vent, about 3 near caudal origin, at which point and earlier the length corresponds with that of a caudal vertebra. No count was given for the type of *T. arawatae* and no counts appear to be available for Australian specimens; approximate counts for three examples 55, 51, 50 precaudal plus 62, 52, 54; the number evidently subject to considerable individual variation in this genus, Fitch (1964) recording for *T. altivelis* 106-122, of which 66-81 are precaudal (these totals, it may be observed, differ markedly from the 88-120 + 174-186 reported for the type species of *Desmodema* Fitch, 1964, i.e. the Australian *Trachypterus jacksoniensis polystictus* of Ogilby, 1898).

(f) Vent. A small simple slit, 474-620 *TLs* units behind snout tip, more caudad in small individuals, subequal to pupil diameter; in our material regularly placed on mid-ventral line, no examples with it eccentrically on right or left side as often in *Desmodema polystycta*. Where course of hind portion of enteric canal is made evident by retained food, it is seen to bend down rather sharply shorter before vent, chord of curve about half of height of body in this region.

(g) Fins. Variation in length to first dorsal, as measured along general antero-posterior axis from level of snout tip, shown in table 1, is largely the result of individual differences in relative height and slope of forehead, the insertion tolerably stable anatomically above 0.4-1.00 eye; fin imperfect in all specimens, from ray-stumps probable number 5-7 (?8); sole 1st ray preserved, specimen (e), 37 mm, 0.64 head, longest intact ray, 2nd, specimen (g), 83 mm 1.3 head, rays simple, apparently smooth, hyaline. Second dorsal originating very shortly behind first, with which in some examples it is connected by low membrane, rising rapidly anteriorly, reaching maximum height at, or somewhat behind, middle of length, extending virtually to caudal base; in five specimens 171-178 rays; rays slender, finely pointed, often filamentous distally, minutely spinigerous throughout most of length on lateral surfaces, proximally on anterior and posterior surfaces; each arising from a broadly subelliptical convex cluster of elevations with 1-2 recognizably spine-like or a distinct acute spine; membrane hyaline, immaculate. Relative height of first dorsal fin, forming nuchal crest noticeably less than in type of *T. arawatae*, much greater than in McCulloch's example of *T. jacksonensis*; as preserved 1.3 head (cf. 1.8, ca 0.25 with mouth protruded). Height of second, as *TLs*, 101-200, $\bar{x}$ 36.5 ± 13.80, significantly negatively correlated with *Ls*, *r* -0.970 (*z* -2.086), *t* 8.862***; 0.7-1.01, $\bar{x}$ 0.88 ± 0.0488 head (cf. 0.76, ca 0.5 with mouth protruded). No anal fin.

Pectoral small, broadly rounded, set about twice as far from dorsal as from ventral profile; base short, set horizontally or somewhat obliquely upward and backward, its *TLs* length 13-25, $\bar{x}$ 17.9 ± 1.51, decreasing in relative size with increase in length of fish, *r* -0.892 (*z* -1.482), *t* 4.415**; length to origin, *TLs*, 108-200, $\bar{x}$ 144.9 ± 14.34, the wide range of relative length largely determined by length of head and like it negatively correlated with *Ls*, *r* -0.974 (*z* -2.175), *t* 9.710***; rays 11 (1 specimen), 12(3), 13(3), mostly simple, occasionally divided distally, smooth, 1st much shorter than 2nd, longest about 5th; length of fin, *TLs* 34-95, $\bar{x}$ 50.3 ± 8.20, negatively correlated with *Ls*, *r* -0.906 (*z* -1.506), *t* 4.791**.

Ventrals inserted very close together, on short base, about one-third eye diameter, behind head by about postorbital head at 121-250, $\bar{x}$ 170.9 ± 16.5 *TLs* units, largest value that for smallest individual with that for largest 141 (minimum for second largest), length to origin and *Ls* showing significant negative correlation, *r* -0.974 (*z* -2.164), *t* 9.565***; while not presenting the impressive fan of the type specimen, in which length is 3.4 in head or of the smaller of the two individuals figured by M'Coy, about 1.7 in head with mouth protruded, this fin in our material is very much longer than pectoral, its length as determined from preserved rays (fins generally with some damage), ranging (for six specimens, smallest with stumps only) from 0.8 to 1.3, $\bar{x}$ 1.03 head, or from 4.1 to 9.5, $\bar{x}$ 6.7 ± 1.12 in *Ls*; relative length (six specimens) and *Ls* negatively correlated at *r* 0.939 (*z* -1.726), *t* 5.443**; rays 8-9, 9th if present minute; as regularly described and figured first ray much stouter than rest, with numerous spines along proximal part of anterior border, distance from second greater than interval between any other two spines, 2nd spine longest.

Caudal peduncle abruptly enlarged terminally to form small globose fleshy mass, lower half, or rather less, of this constituting a distinct heel; attached to hinder border of this 4-5 very small slightly or strongly downwardly curved spines, their general direction in line with main axis of fish; may be enclosed in membrane beyond which tips briefly project; sometimes closely preceded by a larger azygous midventral spine situated shortly behind last pair of lateral line spines; in one specimen, (g), a flexible filiform process 3 mm long just above uppermost spinule. This represents the lower lobe of the originally two-lobed caudal fin that develops at an early stage, it being generally noted that in *Trachipterus* the rays of the lower lobe fragment as the fish grows, their bases persisting as spines — represented in the illustration of the type specimen of *T. arawatae* as six curved processes, the longest somewhat suggestive of a vestigial caudal filament. (It is of interest to note that in *Desmodema*, a genus which, as noted above, has been confused in Australasian literature with *Trachipterus*, the caudal rays are on the same axis as the caudal peduncle and a ventral lobe of the caudal fin is never present.) From an examination of a number of young examples of the three Mediterranean and southeast Atlantic species of dealfishes recognized by him (*Trachipterus arcticus, T. trachypterus, Zu cristatus*) Palmer concluded that characters present in the young persist until a definite developmental stage is attained, a stage that does not appear to be directly correlated with size alone, but nevertheless commonly takes place within the size limits 50 and 70 mm; the larger dimension being well below that of our smallest individual. It is certainly an unfortunate taxonomic circumstance that an accepted species of *Trachipterus* should be based on a specimen with retained larval features.

Above heel on caudal peduncle, posterior border of a continuation as a fleshy pad, its general sense at about 45° to main axis, constitutes the very short base, one-third eye diameter or less, of the persistent lower lobe of caudal carried more or less normal to anteroposterior axis; 8 rays, subequal in length, upper and lower stouter than rest, all minutely spined on both free surfaces; fin missing in two examples, imperfect in one; *TLs* length in specimens of *Ls* 100, 212 mm 480, 401, in specimens of *Ls* 550, 560 shorter, 306, 304; fin, as preserved, in general very narrow rays close together, subparallel, narrowly joined by translucent membrane, not fanlike as in illustrations by Clarke and M'Coy; however in specimen (b) distal half of fin presents a wide irregular plume of whitish and dusky fluffy membrane.

Clarke described and figured the type specimen of *T. arawatae*, 64 mm in length without caudal, as possessing two features, a "little rudimentary [= vestigial] dorsal", between second dorsal base and caudal origin, and, opposite and equal to it, a "low rudimentary adipose anal fin", regarding these as characters unique to his fish. No such structures are reported elsewhere in the Australasian literature, nor are they to be found in our material. It is evident that, as noted by Palmer (1961), who incidentally makes express reference to Clarke's fish, these are to be interpreted as representing the persistence, perhaps to a somewhat longer overall size than usual, of larval structures in the form of portions of fin fold supported by actinotrichia: such lobes were reported earlier in young stages of trichipterids by Emery (1879a,b), Smitt (1893) and Ehrenbaum (1905).

(h) Pterygiophores. The fact that the pterygiophores, embedded and hidden in muscle in most teleosts, are usually visible in dealfishes as a conspicuous palisade occupying up to two-thirds of distance between vertebral column and dorsal profile lends a curious appearance to this fish and to illustrations of it (not depicted in figure of type specimen of *T. arawatae*). The height of the apparent portion of the radial (perhaps supplemented basally by a shallow component and possibly by a small distal one) reaches a maximum near middle of overall length, decreasing rapidly in an early anterior section and more slowly and evenly caudad. Samplings of height at operculum, at vent, and maximum height give *TLs* ranges of 29-50, 35-79, 45-80, respectively, with means of 38.7 ± 3.27, 54.0 ± 5.70, 61.5 ± 4.82. All three magnitudes are negatively correlated with length of fish, r -0.918 (z -1.574), -0.877 (-1.361), -0.880 (-1.376), giving t 5.164**, 4.073*, 4.143**.

(i) Integument. The character of the external surface is diagnostic in Trachipteroidei — scales absent, skin smooth in Lophotidae (*Lophotes* Giorna, 1809, *Emecichthys* Regan, 1907, *Protolophotus* Walters 1957); scales absent, skin with bony tubercles arranged in ill-defined longitudinal bands or pronounced longitudinal ridges in

Regalecidae (*Regalecus* Brünnich, 1771, *Agrostichthys* Phillipps, 1924): in Trachipteridae either scales absent, skin with tubercles not arranged in longitudinal bands or ridges *Trachipterus* Gouan, 1770 or deciduous scales present, either imbricate, cycloid, *Zu* Walters & Fitch, 1960, or non-imbricate, modified ctenoid, *Desmodema* Walters & Fitch, 1960. Genera represented in Tasmania are *Lophotes*, *Regalecus*, *Agrostichthys*, *Trachipterus*, (present paper) *Zu*.

In the present material as preserved the skin is everywhere smooth to the touch except along the lateral line where its spines are evident, particularly when a finger is drawn caudad, and along a very narrow fringe to the ventral border, where the tubercles become spinigerous (see below); striated bones of head slightly rough. Small tubercles, flattish or gently convex, cover all exposed surfaces; least developed in small individuals; closely set, interspaces in some regions subequal to, in other regions decidedly less than, their diameter; in specimen (e), *Ls* 508 mm, about 400-500/sq. cm. Along whole ventral surface, below region of body housing the internal organs, a distinct translucent or subtranslucent pennon-like strip, height immediately behind ventrals equal to, or somewhat exceeding, eye diameter, progressively decreasing caudad; noticeably thinner than body above it. On this strip the tubercles become more evident, especially in its lower half or so, where they increase in size progressively downward, at the same time becoming increasingly elevated mesially to develop distinct projections, finally at ventral border bearing rows (two more or less regular lines, one on each side of fish) of small but tolerably stout subconical, at times slightly recurved spines, their height about twice basal diameter, latter 1-4 in interspaces; in specimen (e) about 15/10 mm in each row.

(j) Coloration. The ground color of our specimens as preserved varies from whitish to yellowish, differences of intensity often characterizing one or other of several longitudinal regions (pterygiophores, along or below lateral line); in general some silvery tinge; one specimen tending towards pale purplish. Fin in general whitish or virtually colorless; specimen (b) with distal part of caudal dusky. Pigmentation of the characteristic four dark spots on each side normally black or nearly so, usually continuous within a well defined border, occasionally in large discrete patches with border less sharp. The locations and relative dimensions of the spots, together with serial numbers of second dorsal rays surmounting them, are specified in table 2; in all cases the left side of the fish has been examined. The color in life is succinctly described as silvery, fins scarlet, Marshall (1925) noting of a large example of *T. jacksonensis* [rendered *jacksoniensis*] "when received at night ... its silvery surface was flowing with phosphorescence". Clarke recorded of the holotype that the collector described the fins as "like brilliant feathers more than fins", continuing "this, coupled with the brilliant silver sides made it [the fish] gorgeous in the extreme".

In our material the pattern of the spots broadly conforms to that familiar from early European depictions, e.g. that of Bushnan (in Jardine 1840, vol.2, pl.5) to illustrations of Australian fish by, e.g. Clarke, McCann, M'Coy — namely, three widely spaced near the dorsal border, the first about one head length behind head, and one near ventral border, more or less under first of dorsal series (this last, generally present in local illustrations, is, somewhat surprisingly, not depicted for the holotype). This widely spread pattern admits of variation, thus the photograph of the holotype of *T. pentastigma* Norman, 1961 presented by Palmer (1961, pl.5, fig.2) — species identified by Palmer as *T. trachypterus* — shows two ventral spots, while of the three dorsal the first lies just behind the head, apparently on the fin. Palmer notes he has seen several Mediterranean specimens with five dark blotches: Günther (1887, p.72, footnote) had earlier defended his *T. ruppellii*, 1861 against question of its validity by observing of his type specimen in respect of the first dorsal spot it "differs from other Mediterranean specimens of the same size which are known to me" (Palmer regards this as "undoubtedly an adult example of *T. trachypterus*").

While with each fish viewed separately our sample would appear to present a constant pattern of spots, reference to table 2 shows each spot exhibits considerable variation in its relative distance from snout tip, the upper value of the *TLs* range being 2,2, 1.8, 1.6, 1.2 times the lower. In general the ventral lies more or less beneath the first dorsal (directly below in one individual, slightly in front in four, slightly behind in two),

TABLE 2

TRACHIPTERUS ARAWATAE Clarke, 1881

Specification of color spots, general location, size, serial number of second dorsal ray surmounting middle of spot in seven Tasmanian specimens of standard length 100-560 mm. Dimensions as millesimals of standard length.

	Ventral spot	1st dorsal spot	2nd dorsal spot	3rd dorsal spot
Length to spot, range	166-360	198-350	374-600	598-780
Length to spot, mean	192.1±30.3	252.2±20.8	457.3±31.7	666.5±24.6
Length to spot, correlation with *Ls*; *r*, *z*	-0.894, -1.442	-0.979, -2.274	-0.892, -1.432	-0.833, -1.197
Length to spot, correlation with *Ls*; *t*	4.462**	10.279***	4.415**	3.363*
Length to spot, mean as percent of mean to first spot	100.0	131.3	238.1	347.0
Vertical axis of spot, range	34-35	24-68	20-43	20-49
Vertical axis of spot, mean	28.5±3.67	41.4±5.32	30.5±3.16	38.4±3.45
Horizontal axis of spot, range	27-50	13-70	34-60	24-40
Horizontal axis of spot, mean	36.7±2.65	31.9±2.65	48.2±3.75	32.8±2.81
Serial number of dorsal ray above middle of spot, range	28-31	32-38	62-70	99-117
Serial number of dorsal ray above middle of spot, mean	28.9±0.446	34.6±0.448	67.4±3.10	107.8±2.80
Distance of spot from body profile, range	16-30	7-54	12-20	25-47
Distance of spot from body profile, mean	20.3±2.04	17.7±7.24	14.8±1.65	36.1±2.94
Distance of spot from body profile, correlation with *Ls*; *r*, *z*	-0.643, -0.879	-0.321, -0.333	-821, -1.161	-0.776, -1.037

while among the dorsal series, the mean lengths to the successive spots are 131.3, 238.1, 347.0% of length to ventral spot. Plotted against the serial numbers of the dorsal spots, these percentages given a significantly linear regression (*t* 177.889**), slope 2.31, intercept 107.83, yielding estimated values 131.0, 238.8, 346.7. The mean of *TLs* lengths to all four spots in general decreases with length of fish from 298.6 in a specimen 100 mm long to 196.1 on one 555 long (200.3 in fish 560 long), with mean 230.5±14.3; *r* -0.919 (*z* 1.581), *t* 5.201**.

It has long been known that in northern hemisphere dealfishes of the genus *Trachipterus* the characteristic early dark spots become wholly obsolete in large individuals. In this connection some data is provided by our material, the more interesting that it is derived from a sample from a single general locality. While in specimens of *Ls* 100, 212, 296 mm the full suite of spots is conspicuous, in the next largest, 444, they show signs, particularly posteriorly, of disintegrating into discrete patches of pigmentation; in the largest but one, 555, all spots are faint or very faint, with on the right side ventral and third dorsal unrecognizable; in the largest, 560, on the left the second dorsal is mainly light brown with only a few small areas with distinct melanophores, the rest barely recognizable, on the right the second dorsal is faint, the fourth very faint,

the first and the ventral absent. Specimen (h) of an estimated standard length 630 mm (caudal approximately an additional 100) is so badly mutilated it has not in general been noted in these observations; so far as can be determined it is totally unornamented.

The range and mean of the vertical and horizontal axes of all spots are set out in table 2. Height exceeds length in the first (ventral) spot in five of the seven specimens, in the second in three, in the third in seven and of the fourth in two specimens; it is equal in first spot in one specimen. With sum of the two axes taken as a measure of overall size, the greatest mean is that of the middle dorsal spot, *TLs* 79.1±14.2, followed in sequence by the first dorsal, 73.4±7.67, third dorsal 69.2±6.28, ventral 66.6±5.03. Size of spot as thus specified shows some evidence of being negatively correlated with size of fish, the values of r (z) for ventral spot, dorsal spots 1.3, and means of all spots for each fish being (all minus) 0.990, 0.751, 0.866, 0.678, 0.860 (2.670, 0.976, 1.144, 0.826, 1.295), significant at much better than P 0.001 for ventral spot, better than 0.02 for third and fifth entries, below this for second and fourth.

The vertical location of the spot as measured by its distance from body profile is variable; in ventral spot 16-30, $\bar{x}$ 20.3 *TLs*, first dorsal 7-54, $\bar{x}$ 19.1, second 7-20, $\bar{x}$ 14.3, third reaching profile in five cases, with 9, 2 *TLs* of it in 2. The superior position of the posterior dorsal spot is evident "in the larger of M'Coy's figures" and in some New Zealand illustrations, though but slightly marked in that of the holotype. Mean distance from profile as a fraction of vertical extent of marking is for ventral spot 0.53, first dorsal 0.80, second 0.34. Correlation of distance with size of fish and first two dorsal spots is in all cases negative; numerical values of r 0.643, 0.321, 0.821 (z 0.879, 0.333, 1.160), of which the last only is statistically significant (t 3.626*).

The serial numbers of the rays of the second dorsal directly above the middle of each of the four spots, recorded in table 2, show an upper limit of 4 beyond a lower of 28, 6 beyond 32, 8 beyond 62, 13 beyond 99 (V 4.2±7.3±2.0, 12.2±3.3, 6.9±1.84). With N number of spots, n = number of ray, the mean count surmounting each of the dorsal set is given by the equation $N = 36.60n-3.28$ with t 16.550*; a distinctly better value (t 28.485) is obtained by using instead of value for first dorsal spot mean of that and value for ventral spot, the parameters of the best straight line then being 38.03, -7.09.

Other than that provided by the spots, ornamentation is relatively insignificant. Most striking feature, fully developed only in its lower half (upper half with pigmentation fragmented) in largest individual, not apparent in largest but one, a vertically elongate marking extending from lower lip to level of tips of premaxillary processes, occupying whole of frontal aspect to this point, mostly black or blackish with one or two transverse lighter, usually more or less horn-colored, bands below line of junction of mobile upper jaw with forehead. In two specimens a complete, in one an incomplete, narrow dark line continuing from premaxillary process to first dorsal base, this expanding terminally in the smallest individual to form a dark brown patch covering pterygiophores of first dorsal. In smallest individual but one a conspicuous narrow black line extending along whole length of dorsal bases, constituted of a series of rectangular blocks, occupying the spaces between the ray bases, each 3-4 times as long as high, height subequal to interspace. This marking more or less clearly recognizable in other specimens, lighter in color and much less conspicuous.

Natural history

Apart from the fact that they have all been collected in shallow water or cast ashore the present specimens provide no information on the natural history of our dealfishes. In the northern hemisphere trachipterids, though probably normally dwellers in deep water (being trawled in up to 1 000 m, and found in the stomachs of deep-feeding albacores, Scombridae, and lancetfish, Alepisauridae) are often captured at or near the surface. Food includes an assortment of crustaceans (particularly euphausids), cephalopods and small fishes (most commonly lanternfish, Scopelidae and lampfish or deepwater smelts, Bathylagidae, occasionally hatchetfish, Sternoptychidae). Little local information on feeding habits is available, though McCann (1953) stated the young and adults of his material feed on the "whitebait" stage of other fish. In specimen (c), *Ls* 212 mm, taken in January at Albatross Island, Bass Strait, the caecum has perforated the body wall on the

right side, protruding for about 10 mm, its tip just in advance of the third dorsal spot, 23 mm before vent: the length of the caecum is diagnostic in allotriognaths, the organ extending in *Regalecus* beyond the vent halfway to tail tip; while stopping short of vent in trachipterids, it ends closer to it than to pyloric valve in adult *Trachipterus*, but in adult *Zu* somewhat closer to valve. On being opened up the fully distended caecum was found to be filled with partly digested remains of numerous small white crustaceans, identified as krill, *Euphausia superba* Dana, by Mr Roger Springthorp, Australian Museum, Sydney.

Genus *Zu*
(Plates 1,2)

Zu Walters & Fitch, 1960, p.445. Type-species, *Trachypterus cristatus* Bonelli, 1820.

Zu sp., cf. *Zu cristatus* (Bonelli, 1820)

Trachypterus cristatus Bonelli, 1820, p.487. Type locality: Gulf of Spezia.
Trachypterus cristatus: auct. 1861-1958. Cf. Palmer, 1961, p.346, who lists references under this taxon to 17 European and American authors; specimens chiefly from the Mediterranean.
Gymnetrus repandus Metaxa, 1833, p.53. Type locality: Gulf of Naples.
Trachypterus bonelli Valenciennes, 1835, p.331. Type locality: Mediterranean.
Trachypterus bonelli Canestrini, 1862, p.266.
Gymnetrus müllerianus Risso, 1840, p.13. Type locality: Nice.
Trachypterus repandus Costa, 1850, p.11, pl. Type locality: Mediterranean.
Trachypterus repandus: Buonaparte, 1846, p.79 (synonymy): Steindachner, 1868, p.676. Canestrini, 1871-1872, p.194. Giglioli, 1880, p.92. Goode & Bean, 1895, p.480. Pietschmann, 1925, figs 1-3.
Trachypterus [sp.] Günther, 1887, p.72 (larva).
Trachipterus jacksonensis: Hamilton, 1916, fig.2 (Nelson, New Zealand). (*Nec Regalaecus jacksonensis*, Ramsay, 1881). [cf. Whitley, 1968, below]
Trachypterus iris: Buen, 1917, pp.23-26, 2 figs. (*Nec Cepola iris* Walbaum, 1792).
Trachypterus gavardi Bounhiol, in Bounhiol & Gavard, 1923, pp.1-4. Type locality: Bay of Algiers.
Trachipterus jacksoniensis [=*jacksonensis*]: Phillipps, 1944, p.120, pl.52 (color) (French Pass, New Zealand) (*Nec Regalaecus jacksonensis* Ramsay, 1881).
Trachypterus arcticus (adult males): McCann, 1953, figs 5,6 (New Zealand). *Nec Gymnogaster arcticus* Brunnich, 1788).
?Zu cristatus Walters & Fitch: 1960, p.445.
Zu cristatus Palmer: 1961, p.346 (with synonymy).
Desmodema arawatae Whitley, 1958, p.45, fig.1 (New Zealand). (*Nec Trachypterus arawatae* Clarke, 1881). [Legend to figure reads "*Desmodema arawatae*. Sketch of a specimen presumably male and doubtless the long-missing original of the illustration (inset) published in 1916 by Hamilton" — cf. Hamilton, 1916, above, who identified his specimen as *Trachypterus jacksonensis*.]

Note on synonymy

From the above table of synonymy it is apparent that northern hemisphere ichthyologists were long content to treat Bonelli's *Trachypterus cristatus* as a genuine member of Gouan's 1770 genus, the first to accept its generic distinctness apparently being Palmer (1961), writing immediately following the establishment by Walters & Fitch of *Zu*. The same conservative attitude was adopted by writers — Hamilton, 1916, Phillipps, 1944, McCann, 1953 — who examined New Zealand examples prior to the establishment of *Zu*, the most striking external features of this genus, the strongly scalloped ventral trunk profile and the usual presence on some fin rays of conspicuous bulbous structures (noted by Palmer as characterizing young stages, but treated by Walters & Fitch as a diagnostic generic character), being interpreted by them as merely features in the growth of *Trachipterus* (as by Phillipps) or as sexual characters (McCann): McCann's observations drew highly critical comment from Palmer (1961, p.348). However, the misidentification in 1968 by Whitley of what he regarded as a specimen figured earlier by Hamilton, who had regarded it

as a *Trachipterus (T. jacksonensis)*, as a member of the genus *Desmodema* Walters & Fitch 1960 introduced a positive element of confusion that, as made evident in a table of dealfish generic and specific names in Australasian texts given above in observations on *Trachipterus arawatae*, later extended rather widely through the relevant literature. No representative of *Zu* appears hitherto to have been reported from Australian waters. Some significant features, additional to trunk outline and fin-ray ornamentation, that distinguish *Zu* from the two other trachipterid genera are noted in a table included in observations above on *Trachipterus arawatae*. For discussion of taxonomic status of present specimen, see below.

Material

A specimen collected at East Inlet, Stanley, northwest coast, by Mrs H. Reeman, 27 July 1972, Q.V.M. Reg. No. 1972/5/511; label notes "Pink and silvery grey, red on fins: beachwashed". Tail broken at 285 mm behind snout tip, a further 120 mm before caudal fin, while still attached (barely) considerably contorted, giving standard length 405 mm; caudal fin filamentous distally, possibly imperfect, its present length 120 mm, giving total length 525 mm or 525+ mm.

Dimensions

All dimensions are recorded as millesimals of standard length, 405 mm. Length of head 136, maximum depth of head (overall maximum) 156. Eye 46. Interorbital 27. Snout 44. Length to origin, to termination of first dorsal 67, 88; to origin of second dorsal 94, of pectoral 56, of ventral 146. Length to vent 146. Depths at 10 equal intervals along anteroposterior axis 155, 111, 91, 62, 37, 20, 13, 10, 9, 6. Distance from dorsal profile of lateral line at 10 equal intervals (including origin, termination) 44.4, 55.6, 69.1, 71.6, 67.2, 64.2, 63.0. Oblique length of pectoral base 14, length of longest ray 39. Length of first ray of first dorsal (filamentous, longest preserved) 617, of second ray 494. Second dorsal rays: first 17, at level of operculum 54, at vent 91 (about maximum). Length of longest gill raker 57. Length of middle gill filament on first arch 57. Lengths to (in parentheses depths at) tips of main ventral trunk scallopings 59(128), 81 (153), 128(158), 214(131), 274(121), 388(101).

Proportions

Some conventionally reported ratios are noted below. Length of head 7.4 in standard length. Lengths to origins of first dorsal 15.0, second dorsal 10.7, pectoral 7.6, ventral 6.9, all in *Ls*. Length to vent 3.80, depth at vent 12.5, maximum depth 6.4, all in *Ls*. Snout 3.06, eye 2.97, interorbital 1.68, first dorsal base 6.47, pectoral base 10.0, all in head. With length of head as unity, lengths of trunk, tail are 1.63, 1.74.

As has been found to be the case with the sample of *Trachipterus arawatae* examined above, the depth can be codified in simple formulas, 10 measurements of depth taken at equal intervals along the anteroposterior axis between (and including) snout tip and end of caudal peduncle being such that when log D is plotted on log N, the inverse serial number of the measurement (i.e. counting cephalad) two statistically significant straight lines with widely differing slopes are obtained. For N^1 = {4-10}, log D = 2.8426 log N^1 -0.6415; for N^1 = {7-10}, log D = 0.4787 log N^1+0.7881. For these relations we find r 0.997 (z 3.262), 0.992 (z 2.774), giving t 29.087*** (*d.f.* 5), 11.281** (*d.f.* 2). The two sets intersect at N^1 = 7. It would appear the two segments relate to the preanal and postanal sections of the fish (known in *T. arawatae* to exhibit length growth gradients of differing sign and magnitude), the abscissal length of the set N^1 = 4-10 (anterior part of fish) constituting 0.398 of the abscissal scale, cf. length to vent 0.357 standard length.

As with *Trachipterus arawatae*, a formulation with first and second depths averaged, and nine entries then plotted against terms of the Fibonnaci series as abscissae yields a significant result.

General description

(a) Head (plates 2 and 3). Head moderate, length subequal to height, strongly compressed; anterior profile from upper lip to just above level of orbit straight, at 40°, above which exposed edges of frontals bounding groove in which premaxillary processes are housed are elevated above premaxillae, the profile here rising more steeply, at 50°, for

about half an eye diameter, a slight notch separating it from dorsal base, origin of base extending forward very slightly beyond frontal profile immediately below it. Profile at gape briefly rounded, lower jaw then extending down and back, at much the same angle to horizontal as main upper profile, to below anterior border of orbit, here meeting a lobe where branchiostegal membranes are attached to isthmus. Maxillary plate subovate, narrowing above to end in a digitiform process, broadly rounded below, its length 1.85 its width, subequal to eye; strongly striated, striae radiation from point near upper border, about 25, median 2-3 widest, highest, bifid distally, anterior lateral proconcave, posterior lateral linear. Mouth of specimen permanently slightly protruded, the exposed fleshy strip marking point of disjunction on anterior profile, at level of upper border of pupil, about a pupil wide; in these circumstances it is not feasible to determine accurately position of maxilla with mouth fully closed, but from structure of head here it would appear to reach beyond level of middle of eye. Upper lip rapidly narrowing backward. Inferior surface of lower jaws increasing gradually in width forward, ending anteriorly in a trilobate expansion, the median lobe, smallest, briefly bounding symphysis on either side; lateral surface widening backward with truncate termination above lobe at junction of branchiostegal membranes on each side with isthmus. Frontal aspect of head with a broad subtriangular region, about 1.5 times as long as wide, widest below, bounded by the prefrontals, at their lower termination in contact with a forwardly and upwardly directed fleshy lobe continuous below with an oblique very narrow flexible strip bounding eye between 9 and 7 o'clock (left side viewed); this strip continuous below with an area, concave in front convex below, extending down to level of inferior tip of preoperculum, and extending above to top of orbit, hind edge of which it narrowly borders; anterior portion of this area silvery with some slight rigidity, but yellow hinder portion almost the consistency of flesh (corresponds to area noted above in description of *Trachipterus arawatae* as yellowish, fleshy). Below upper triangular region frontal aspect continues down at approximately same width to gape, surface here distinctly convex. Preoperculum lunate, chord of proconcave anterior border subequal to exposed lengths of premaxillary processes, and to distance between most convex point on convex posterior border and highest point on orbit; silvery, tolerably rigid save for extremely narrow colorless membranous border; numerous well developed striae radiating from near middle of anterior border, lowermost leaning forward. Operculum broadly subtriangular, 1.5 times as long as high, originating above near level of middle of pupil, upper border virtually straight sloping back and slightly down, posterior border of two subequal concave arcs separated by bluntly rounded lobe, with 2-3 small and imperfectly spinous processes representing ends of striae, which here form a small patch of short ridges, overall subvertical, somewhat downwardly concave, their general sense almost normal to that of some 25 strong striae forming a fan centred at anterosuperior angle of plate. Suboperculum large, bounding preoperculum up to horizontal level of opercular lobe, its width subequal throughout, about one-quarter vertical height of plate; covered with striae originating near middle of anterior border, radiating up and down in somewhat proconcave arcs, their general sense approaching vertical near inferior border of plate. Interoperculum small, subtriangular, striate. Orbital rim elevated. Some irregular rugosities above and in front of eye. Nostril single small pore at level of upper border of pupil, nearer eye than snout profile. Eye large, its diameter in head equal to its distance from dorsal profile at origin of nuchal crest (highest point on profile), 1.5 in distance from ventral profile directly below it, its shortest distance from front of gape subequal to that from hindmost point of operculum. Lower jaw with 4 teeth in left ramus, 3 subequal 1 decidedly smaller, 5 in right ramus, 1 about 1.5 times as long as each of 3 others, 1 minute; subconical, acutely pointed, erect. In upper jaw on left 6, 2 small; on right 6, 5 subequal, 1 minute inserted just internal to 3rd from front; conical, acute, strongly inwards, somewhat downwards, tips of innermost of a pair on each side of synphysis very close together, interval about half length of tooth. Teeth on palate, if present, not detected. Gill rakers on lower limb of anterior arch 8, set rather closely, briefly enclosed in membrane proximally, gradually decreasing in height and increasing in relative basal width downwards, uppermost slender, rodlike, subequal to adjacent gill lamellae, others tending to become more or less spatulate; most (possibly all) with 1-3 spinules. Branchiostegals 6, membranes not uniting across isthmus, inserted almost contiguous beside a lobe at posterior end of isthmus.

(b) Trunk and tail. Upper profile of trunk and tail virtually linear, highest point at origin of dorsal fin, above middle of eye (contrast *Trachipterus arawatae*, our material of which shows some small rise to a maximum briefly behind dorsal origin). Lower profile of trunk markedly scalloped, with three recognizable minor emarginations anterior to ventral origin, first small notch, half as deep as long, bordered in front by a rounded process immediately in advance of lowest branchial ray, second and third very shallow, their chords subequal; behind ventral base, for a distance half that between base and first branchial ray, two deep scallops bordered anteriorly by somewhat hooklike processes, length of the first subequal to one pupil diameter, that of the second twice as great, hind border of posterior process in advance of vent by longitudinal extent of vent, reaching below level of body immediately behind it by about one-sixth of chord of scallops, its own chord equal to its distance below lateral line at this point, the line here rather more than three times as far from dorsal as from ventral profile. Behind vent height soon becomes small and tail continues back to its termination in an extremely attenuate form. At a length of 285 mm, or 0.7 of standard length the specimen is broken, the rest of the tail barely attached and much distorted. In the intact half of the tail ventral profile slopes progressively backward and upward, not decisively scalloped, but with some slight sinuosity, particularly anteriorly.

Whole trunk and tail tolerably smooth, finely reticulated with scale-pockets, deciduous scales lost. Below an arc from about half an eye diameter behind ventral fin to end of last scallop, just in advance of vent, a conspicuous thinner more flexible silvery fleshy flap, wholly without tubercles found here in *Trachipterus arawatae*.

Lateral line

Originating against uppermost point of operculum about at level of superior border of orbit, directly distant from eye by half eye diameter, curving down gently for a head length behind head, its distance from dorsal profile now subequal to that from ventral profile at bay of first main scallop behind ventral fin, thereafter sloping down subparallel with dorsal profile to about 23 mm behind vent, continuing for about 4 mm now parallel with ventral profile, and apparently (as described by Phillipps) joining its fellow of the opposite side; a well defined groove enclosing small low regular elevations, length equal to interval, each with minute inconspicuous but readily felt spine; exact course of line defined by a series of ten equidistant measurements of distance from dorsal profile note in section on Dimensions, above. The termination of the lateral line shortly behind vent in agreement with diagnosis of *Zu* by Palmer (1961), in disagreement with that by Walters & Fitch (1960) is discussed in a subjoined section on the taxonomic status of the Tasmanian specimen.

Along the ventral profile behind lateral line termination on each side of tail a series of strong rounded or elliptical bucklers, striated radially from small circular pit at summit. Also along profile on each side a row of strong subconical spines, first 3-4 smaller than rest; most arising from middle of boss, some from some other part of it, some between bosses; mostly directed downwards, occasionally somewhat sideways; on two sides generally opposite, at times alternate or irregular; 26 on one side to break in tail of specimen, approximately 30 behind this (cf. Phillipps, 54).

Fins

First dorsal originating about above middle of eye, front of base highest point on dorsal profile, projecting very slightly in advance of frontal profile immediately below it; base less than half eye; formed of six contiguous subtriangular bosses, pointed above; arising from each a stout rounded spine, first with a few minutes spines proximally; 1st spine intact, length 617 *TLs*, filamentous distally, whitish throughout lacking serial bandings or enlargements; 2nd imperfect, length ca 494 *TLs*, 3rd 4th 5th represented only by stumps (all with some indications of dark banding); 6th 300 long, with seven dark brown segments 5-6 mm long, length 1.5-2 times interspace; these dark segments presenting no morphological difference from intervals between them (contrast lobate membranous expansions described and figured by Phillipps, and apparent vestiges of these on caudal of present individual).

Second dorsal originating behind termination of first by 6 *TLs*, distant from last ray of crest by about interval between that ray (6th) and 4th; 1st ray short, one-eighth head length, length then increasing rather rapidly to more than thrice this at level of operculum, about five and one-third times at level of vent, this being about maximum height; rays rather stout basally, tapering rapidly, acute distally, interval about twice basal diameter; each arising as if from a sack from a more or less globose enlargement at base, enlargements mostly continuous with basal ridge; both surfaces distinctly rough to the touch, minutely, almost invisibly spinose; rays to level of vent 49, to break in tail of fish at 0.70 of standard length 108, possible total round 140 (cf. Phillipps 111, Palmer 120-150: these rays are very brittle; part of one found in specimen jar bore distinct black paired flaps that appeared clearly to represent vestigial vesicles).

Caudal, reported by Phillipps as having 14 rays and being a single fan, diagnosed by Palmer as being in two parts, upper fanlike of 8-12, lower of 1-5 rays, is in a poor state of preservation in our specimen, especially distally where the rays, some filamentous, are imperfect and inextricably tangled: satisfactory description is hence not possible; as far as can be determined the position is as follows. Length at least 300 *TLs*, quite possibly more; at base 10 closely set rodlike transparent rays, upper two very slender, minutely but profusely spinose, terminally a tangled mass; immediately below these, three rays, uppermost about 200 *TLs* long, lowermost about 150 long, each with two barely developed (vestigial?) dark membranous flaps in basal portion and with one-two morphologically undifferentiated dark bars in distal portion; between these two rays an imperfect ray of different appearance, apparently regularly noded; below these three rays, which are mainly colorless, a slender twisted, apparently braided black flexible rope-like strand, its end not separable from tangled ends of other rays; below its insertion some contorted bases, possibly four, of black somewhat leathery rays, one extending back to become braided into main dark strand.

Pectoral very small, rounded, originating below opercular border, about level with bottom of maxillary plate (mouth closed); base horizontal, two-thirds eye; 12 simple rays, first minute, longest 40 *TLs*, less than eye diameter.

Ventral originating about under hindmost pectoral ray, almost contiguous with its fellow on other side; on both sides rays reduced to stumps not exceeding 5 mm in length; six rays, 1st much stouter than rest, its stumps on either side with one spine; base a fleshy pad, subequal in length to pectoral base.

Coloration

The ground color, noted on collection as pink and silvery grey, now mainly whitish or yellowish, with some silvery tinge; fins originally red now all colorless except matted mass of distal parts of caudal rays, predominantly dark brownish, in places black. Frontal aspect in general brownish; fleshy regions exposed by partial protraction of mouth dark cream or pale brownish; upper lip with inferior border dark, rest lighter, brown; lower lip very dark brown anteriorly, off-white behind with some brownish patches (possibly originally wholly brownish); isthmus yellowish behind, dark brown in front. Lateral aspect of head in general silvery, except large sublunate region below eye, pale yellow.

On trunk markings above lateral line faint brown, deepening somewhat caudad; five main items, all extending to, or virtually to, dorsal profile; more or less circular, increasing in size backward, first somewhat indeterminate, diameter about half eye, subcontinuous in front with vague streak bordering first dorsal base, last extending three-fourths of distance to lateral line here; below lateral line some indeterminate duskiness just behind head, three longitudinally subelliptical brownish markings above light strip bordering ventral profile above two main scallopings behind ventral fin; hindmost extending briefly behind terminal process of last scallop, here reaching inferior border and embracing whole white vent. On tail up to point at which it is broken markings, darkening posteriorly from mid to dark or very dark brown, are in sequence caudad as follows: rounded, diameter half eye, touching dorsal profile above, partly behind, level of vent; large, subrectangular, from ventral profile to within one-fifth of its height of dorsal profile; complete bar, height nearly twice width, latter two-thirds eye, distance from marking in front subequal to width of either; after slightly greater interval, darker

band, 1.5 times as long as high, very dark at each profile; an interval, a little longer than last marking, bright silvery in its inferior two-thirds or more, narrowly bordered below finrays by dark strip; from here to break in tail, i.e. for some four-fifths of an eye diameter, wholly blackish; the damaged and contorted partly attached portion from here to caudal origin largely blackish, with some off-white. An obscure regularly interrrupted dark line along second dorsal base.

Taxonomic status of present specimen

Given the known ontogenetic variability of the group and with the local fauna so little researched, the relation to recorded Australasian material of the new specimen presents some difficulty, particularly so in the absence of direct comparison of material. Judging on the grounds of published information, there would seem to be no obvious caveat against recognition of consepcificity of the New Zealand specimens, nor against acceptance of identity with them of the Tasmanian fish. Somewhat more problematical is the relation of the Australasian representative of *Zu* to a species or to species with an extralimital distribution, the precise taxonomic scope of the genus in other waters not yet having been definitively resolved.

Zu was described (Walters & Fitch 1960) in a general review of the families of the suborder Trachipteroidei without mention of any species other than the genotype, and in a subsequent paper by one of its co-authors (Fitch 1964) on the Trachipteridae of the eastern Pacific Ocean the genus remained monotypic, its distribution being described thus: "Known from all tropical and temperate world seas, but rare in the eastern Pacific, having been found off Newport Beach, California, off Cedros Island, Baja California, and east of the Galapagos Islands, Ecuador". In his review of the family in the Mediterranean and northeast Atlantic, Palmer referred to *Zu* half a dozen nominal species of *Trachipterus* (and the synonymic *Gymnetrus*), and noted of the larval specimen, 32 mm in standard length, taken by the *Challenger* near the Philippines and reported on by Günther (1887) and of another specimen, 31 mm in standard length, taken by the *Discovery* off the Cape of Good Hope they were both "morphologically indistinguishable from *Zu cristatus*", adding "it may be that the genus *Zu* is monotypic"; observing, however, he had not included in his table of synonymy two species reported outside the region dealt with in his review, namely, *T. ijimae* Jordan and Schneider, 1901 from Japan, *T. semiphorus* Bleeker, 1868 from Amboina. He concluded by giving the distribution of *Zu cristatus* as: "Mediterranean, Madeira, Azores, Durban, ?Cape of Good Hope, ?Philippines, ?New Zealand".

Setting aside the Australasian confusion in the systematics of the Trachipteridae (a significant factor in the later part of the history of which apparently was the fact that Whitley, picking up *Desmodema* Walters and Fitch, 1960, apparently interpreted it as an overall substitute for *Trachipterus* Gouan, 1770, and proceeded to apply it to specimens correctly attributable to Goüan's genus, e.g. Clarke's holotype of *T. arawatae*, and at the same time to specimens, e.g. that of Hamilton (1916, fig.2) properly referrable to *Zu*, this genus, though established in the same paper as *Desmodema*, seemingly being wholly overlooked), the matter of the nomenclatural status of the present specimen has been more or less one of plain sailing. However, the lateral line raises a problem, published accounts of its course in differing markedly in papers by Walters & Fitch (1960), Palmer (1961), and Fitch (1964).

In the definition of the family Trachipteridae Walters & Fitch (p.444) state "The lateral line terminates at the base of the caudal fin in the ventral part of the tail, or extends onto the ventral lobe of the caudal fin", while noting (p.445) in the diagnoses of their new genus *Zu* it there "is straight on the trunk, wavy on the tail, and extends onto the caudal filament between the rays where it is once more straight". In marked contrast Palmer, in diagnosing *Zu*, sites its termination just behind the vent, writing (p.345) "Lateral line straight as far as the ventral constriction where it joins the lower edge of the body" (the meaning of the not wholly felicitous expression "ventral constriction" is made evident by an earlier entry, "The caudal region is sharply constricted dorso-ventrally behind the vent"). Hence, if Palmer's specification is unreservedly accepted, it would appear that *Zu cristatus*, as recognized by him, does not formally qualify as a member of the Trachipteridae as that order is defined by Walters & Fitch!

The New Zealand dealfishes here relegated to *Zu* — that of Hamilton (1916, fig.2) also that regarded as Hamilton's fish re-figured by Whitley (1968, fig.1); that of Phillipps (1944); that of McCann (fig.6; position of lateral line not traceable in fig.5, which, however, depicts a fish closely comparable with Phillipps') — all show the obvious lateral line as ending just behind the ventral scalloping, i.e. just past the end of the trunk. In our specimen the lateral line, which from just behind the head runs down and back virtually straight, ends barely above the ventral profile beind the vent by 27 mm, or 0.4 head; its quite short section on the tail continuing to be linear; subparallel now with ventral profile, and apparently finally turning down to make contact with its fellow on the opposite side.

An adequate reconciliation on the different locations of the point of termination as noted by Walters & Fitch and by Palmer turns on an interpretation of what is and what is not to be regarded as the lateral line. In a paper published later than the three cited above Fitch (1964) in a description of *Zu cristatus*, based on a juvenile, *Ls* 213 mm, and an adult, *Ls* 535 mm, wrote " The lateral line commences on the nuchal crest about half-way between the eye and the dorsal contour, curves downward to just over the opercle and then progresses posteriorly in a relatively straight line, reaching the ventral contour about one-half head length behind the anus. From that spot to the caudal fin, the lateral line undulates as scales from opposite sides of the body alternately align along the ventral contour". This specification is applicable to our specimen, also, as far as can be determined, to the New Zealand dealfishes here relegated to *Zu*. The preferable interpretation of the lateral line would seem to be that adopted by Palmer, namely, the conspicuous conventional visually obvious groove terminating at the ventral profile less than a head length behind the vent.

Family Emmelichthyidae

This family (members of which have been referred in Tasmanian texts also to three other families, Percidae, Erythrichthyidae, Pristipomatidae) is formally represented in the local list by a single species, *Emmelichthys nitidus* (Richardson, 1845) recorded from all Australian States (and New Zealand). However, it may be noted it is possible the specimen of a second species, *Plagiogeneion rubiginosus* Hutton, 1876, taken by the *Endeavour* on the "Eastern slope of Bass Strait, between Gabo and Flinders Islands, outside one hundred fathom line" (McCulloch 1914, p.104) was collected in what are conventionally accepted as Tasmanian waters.

Genus *EMMELICHTHYS* Richardson, 1845

Emmelichthys Richardson, 1845, p.47. Type-species, *Emmelichthys nitidus* Richardson.
Erythrichthys Temminck & Schlegel, 1845, p.117. Type-species *Erythrichthys* sp. Temminck & Schlegel. Preoccupied by *Erythrichthys* Bonaparte, 1831 (Pisces).

Emmelichthys nitidus Richardson, 1845

Emmelichthys nitidus Richardson, 1845, p.47, pl.29, figs 7,8. Type locality: Western Australia.

Tasmanian history

Though R.M. Johnston, doyen of Tasmanian ichthyology, included this species (as *Erythrichthys*, family Percidae) in his first catalogue (1883a, p.111), he did so only by virtue of its appearance in the MS list of Morton Allport. In a paper on six rare fishes recently captured in Tasmanian waters (1885, p.254) he observed (under Pristipomatidae) of an example, "My attention was first drawn to this specimen by Mr. Morton [Director, Tasmanian Museum], who obtained it in one of the fish-stalls. It was captured with flounders [commonly associated in mainland States with the pilchard, *Sardinops neopilchardus* (Steindachner, 1879)] in shallow water near Sorell in the estuary of the Derwent on 15th May. This is the first representative of the species seen by me during a residence of 14 years in Tasmania. I have reason to believe, however, that it is seen by fishermen occasionally in the neighbourhood of Swansea"; noted, in second list (1891), as "rare". In his first list Lord (1923) referred it to Erythrichyidae, in his second (1927) to

Emmelichthyidae; both papers simple name-lists unaccompanied by comments. Lord & Scott (1924), who adopt Erythrichthyidae (p.11), state "rarely obtained in the mature state, but instances have been known of immature forms occurring off the South Coast. Mr W. Gates, of Hobart, was the first to secure specimens of this species in Tasmanian waters" (p.66). Some notes are here given on the first specimen received by the Queen Victoria Museum, an example about two-thirds grown, *Ls* 176 *Lt* 206, taken by Mr D. Wright at The Gardens, north-east coast, December 1980, "found with schools of mackerel" (Q.V.M. Reg. No. 1981/5/1).

Meristic characters

D. XIII, 10. A. III, 10. P. 22. V. I, 5. L. lat. 95.

Dimensions

The principal characters are recorded as millesimals of standard length. Length to origin, termination of first dorsal 438 710, of second dorsal 710 824, of anal 710 830. Length to pectoral 273, length (total) of fin 227. Length to ventral 324, length (total) of fin 170. Length to vent 685. Head 270. Snout 74. Eye 63. Interorbital 74. Depth at front of eye 111, back of eye 139, opercular margin 188, vent 185; maximum 199, depth of caudal peduncle 73.

Aspects of form

(a) Anal spines. Following a pattern frequently encountered, the logarithmic lengths of the three spines are significantly linear on logs {1 2 3}.

Log L = 1.0706 log N + 1.0392; t = 18.188*; estimated (measured) lengths, *TLs*, 10.8 (10.9) 22.4 (23.9) 35.4 (34.7).

(b) Ventral rays 1-4. As in many fishes, the rays postaxial to the spine — ray 1 conventionally defined (Scott 1974) as that furthest from the spine — are specified by $L = b\ N^k$, with here, as customarily, N = {1 2 3 4}.

Log L = 0.2212 log N + 1.9822; t 16.578**; estimated (measured) lengths, *TLs*, 97(97) 113(115) 124(125) 132(131). The length of the spine is 110; that of ray 5 is 127 (as usual, >3 <4).

Coloration

Upper half of body almost uniform slaty, with some silvery lights; lower half brownish. Head much like body; anterior two-thirds of upper surface of snout dark brown in parts approaching black (tip scaleless); an arc of pale yellow behind eye (scaleless). Dorsals dusky, anal pale yellowish, ventral dark yellowish, caudal chiefly yellowish with two blackish longitudinal pennons at base.

Family Pempheridae

This family, the members of which are characterized by a deep compressed body, single short dorsal fin, long anal fin and usually a very large eye (this feature suggesting the vernacular name bullseye, other vernacular names being sweepers, beach-salmon), is represented in Australia by eight or (Whitley 1964) nine species of which two, *Liopempheris multiradiata* (Klunzinger, 1879) and *Parapriacanthus elongatus* (McCulloch, 1911) are recorded from Tasmania. Neither species is included in the first catalogue of Johnston (1883a) but the former appears in the second (1891) as the synonymic *Pempheris macrolepis* Macleay, being referred as in the Australian catalogue of Macleay (1881) to the Kurtidae. Lord & Scott (1924) observe of *Liopempheris multiradiata* "seldom taken in Tasmania" but offer no comment on *Parapriacanthus elongatus*.

While *Parapriacanthus elongatus* was correctly placed in Pempheridae in the earlier Tasmanian list of Lord (1923) where it remained in the synopsis of Lord & Scott (1924), in Lord's later list (1927) it was incorrectly transferred to Priacanthidae, a different family of fishes (Bigeyes), none of the three Australian representatives of which has been recorded (McCulloch 1929, p.165) south of New South Wales.

The Pempheridae, which have a virtually worldwide distribution, closely resemble the Berycidae both superficially and osteologically, differing trenchantly from them, however, in lacking additional soft rays in the ventral fins, being provided only with five found in most acanthopterygians. Both the Tasmanian species are referable to that group of

genera in which the eye is large, the origin of the dorsal lies in the anterior half of the standard length and the maxilla is noticeably expanded distally.

KEY TO PEMPHERIDAE RECORDED FROM TASMANIA

Depth of body >1.5 (about twice) head length.
    Anal originating below middle of dorsal fin base, its base with some scales: rays >30 (31-34). L. lat. <60 (46-50). Teeth in jaws mostly uniserial ..... *Liopempheris multiradiata*
Depth of body <1.5 (subequal to) head length.
    Anal originating below posterior end of dorsal fin base, its base without scales; rays <30 (24-27). L. lat. >60 (68-72). Teeth in jaws pluriserial ..... *Parapriacanthus elongatus*

Genus *PARAPRIACANTHUS* Steindachner, 1870

Parapriacanthus Steindachner, 1870, 1.623. Type-species, *Parapriacanthus ransonneti* Steindachner.
Pempherichthys Klunzinger, 1871, p.470. Type-species, *Pempherichthys guntheri* Klunzinger.

Parapriacanthus elongatus McCulloch, 1911)

Pempheris elongata McCulloch, 1911, p.47, pl.4, fig.1. Type-locality: Bass Strait.
Parapriacanthus elongatus McCulloch, 1929, p.235: Whitley, 1964, p.46 (species 1271).

Material

Two specimens, *Ls* 69.7 70.9 *Lt* 87.9 89.5, taken by Mr Shane Down in March 1980 6 km north of Eddystone Point, east coast, in 26 m (Q.V.M. Reg. No. 1980/5/43). Where two entries for the same feature occur below that given first is for the smaller individual.

Meristic characters

D. V, 9 10. A. III, 24. P. 18. V. I, 5. C. total rays 18. L. lat. 69 67. In general these counts are in agreement with those given by McCulloch (1911); however, spceimen (a) has one fewer dorsal ray and one more ray in caudal (all elements).

Dimensions

Though McCulloch reports a number of proportional magnitudes (see below) he provides no absolute measurements other than the length range (16 specimens 90-132 mm). The following dimensions are recorded as thousandths of standard length.

Total length 1261 1262. Length to origin termination of dorsal 443 451 617 601, of anal 623 609 915 884. Length to origin of pectoral 316 298, length (total) of fin 307 315. Length to origin of ventral 350 324, length (total) of fin 194 206. Head 339 336. Snout from tip of lower jaw 60 66, from tip of upper jaw 55 56. Eye 128 126. Orbit 142 141. Interorbital 88 92. Depth at front of eye 165 154, back of eye 280 255, opercular border 330 324, vent 294 275; maximum 337 339, of caudal peduncle 99 100. First dorsal ray 263 —, last 72 75. First anal ray 128 118, last 36 —, longest (5th) pectoral ray 287 278. For dorsal spines anal spines ventral rays see Aspects of Form, below.

Proportions

Proportional dimensions recorded for the type material are given below for the present specimens (McCulloch's values in parentheses). Depth 2.97 2.95 (2.7-3.1) in standard length. Caudal peduncle 1.29 1.26 (1.3) in eye. Orbit 2.39 2.38 (2.4) in head, 1.61 1.54 ("much greater than") interorbital, which is 0.26 0.27 ("rather more than one-fourth") head, or 1.47 1.39 snout measured from tip of lower jaw or 1.60 1.64 snout measured from tip of upper jaw ("one-third longer than the snout"). Length to dorsal origin 0.54 1.56 ("usually somewhat less, sometimes rather more than half") total length. Last dorsal spine 0.9 — ("about two-thirds") first ray, which is 1.4 — ("a little longer than") space between end of snout and hinder orbital margin. Anal base 1.68 1.73 ("1.5 to 1.7") dorsal base, its anterior rays 0.49 — ("only two-thirds, or less") first dorsal ray.

Other diagnostically useful proportions include the following. Head 2.95 2.98 in standard length, 3.72 3.76 in total length. Pectoral 1.10 1.07, ventral 1.75 1.63 in head. Depth of caudal peduncle 3.42 3.36 in head, 0.86 1.16 in its length. Depth at vent 0.87 0.81 greatest depth.

Coloration

Available accounts convey little or no idea of the quite bright color pattern. In his account of the original material trawled off Flinders Island, Bass Strait, in 73 m and off Wilsons Promontory, Victoria, McCulloch (1911, p.48) remarked, "Upper surface of the head, back and upper portion of the sides closely speckled with microscopic brown dots which give them a greyish colour. Breast, lower jaw and lips more or less similarly dotted and the specks also extend onto the dorsal and caudal rays. Otherwise colourless in preserved samples". Upwards of sixty years later Scott *et al.* (1974, p.216), repeating the observations on the dark spots, add only "Colour of body greyish above, lighter below". Some notes made on Mr Down's specimens shortly after their receipt at the Museum when they clearly retained most of their original coloration are summarized below.

Lateral line prominent, yellowish; trunk and tail above it dark sage green with a hint of brownish occasioned by the minute spots; lateral surface behind level of anal origin pink with some silvery sheen, the pink deepest in a narrow curved band immediately above anal base and following its course, in advance of anal in general bright silvery with underlying tinge of pink, an obscurely delimited patch of plumbeous immediately in advance of and extending above pectoral base. Head chiefly pinkish or pinkish with silver lights, iris deep grey with external annulus of pale grey, pupil whitish. Dorsal rays deep pink in proximal two-thirds rest whitish, membrane hyaline. Anal very pale cream except for basal sheath which is salmon pink. Pectoral white. Ventral mostly whitish: between the fins a dark plumbeous strip beginning just behind their origin and extending well beyond their tips. Caudal mostly pink, a conspicuous dusky longitudinal mark along upper border, lower one or two rays white. After a week in formalin the overall color was greyish becoming somewhat lighter ventrally: the general color below the lateral line has become essentially yellowish behind the vent, silvery in front of it.

The small dots on trunk and tail above the lateral line to which area they are almost entirely confined are numerous; they would appear to constitute a good specific character in preserved material. Their extension on to the dorsal rays is here confined to the proximal half of the anterior half of the fin, where they are intense; on the caudal they are prominent on the upper 5-6 rays (more so in the smaller individual) but are lacking elsewhere in the larger fish, while in the smaller they form a small patch on the proximal one-sixth of the rays above the lowermost which is immaculate. On the head the spots cover most of the dorsum in places becoming very closely set and even coalescent, forming very dark almost black patches or streaks, the most noticeable aggregations being blotches above the upper lip and below the lower lip and stripes on the lips themselves; on the ventral surface where they extend back to the level of the end of the rictus they are dispersed.

It is of interest to note that in the recently published Coastal Fishes of Southern Japan (Matsuda, Araga & Yoshino 1975) all four pempherids shown in color in plate 33 are brightly tinted. The type-species of the present genus, *Parapriacanthus ransonetti* Steindachner, 1870, is chiefly pinkish, with, as in the present fish, some obscure leaden tinge behind the head and again as in these with a small dark area at the tip of the upper caudal lobe. Schultz (1953, p.561) has observed of the translucent pinkish *Parapriacanthus beryciformes* Frankz, 1910 "on some specimens tips of caudal lobes black pigmented". There is here no green strip above the lateral line as in *P. elongata*; however, its place is taken in another species, *Pempheris oulensis* Cuvier, 1831, by a similarly disposed band of brilliant blue.

Comparison with original account

Apart from the extended information on coloration now available some quantitative variations from the original account, mostly of a minor nature, are evident from the data recorded above. Several other differences are here noted. Maxilla extending to below 0.5 0.6 eye, rather further than figured, its hind end considerably expanded, the distal border markedly excavate. A fleshy circumoral ring, not clearly evident in illustration,

supplemented by a contiguous fleshy or adipose crescent embracing anterior one-third or more of eye, extending backward above for a lesser distance than as depicted, widest at 9 o'clock (right side viewed) where it extends forward to make contact with and partly or wholly to surround the closely approximated nostrils. This structure would appear to represent a rudimentary or vestigial adipose eyelid, the presence of which as a well developed structure is employed by Marshall (1964) and Munro (1957) to key off *Leptobrama* Steindachner, 1879 (synonym *Neopempheris* Macleay, 1881) with one Australian species, *L. muelleri* Steindachner, 1879 from other genera occurring in Australian waters. The location of the nostrils is in our material lower relative to the eye, lying on instead of above horizontal level of upper border of pupil, but on the other hand higher relative to mouth, occurring well above instead of level with upper lip, latter higher in general head profile in illustration. Border of preorbital, shown as distinctly sinuous, swinging in towards eye at level of lower one-third of latter, exhibits some slight concavity in this region on left side of (b) but is in the other individual virtually linear or overall convex. A shallow notch in opercular border defined above and below by a pair of very weak flat spine-like projections (noted in text as almost hidden by scales, not clearly evident in figure), the lower level with inferior border of pupil, the higher just above level of pupil, below origin of lateral line by a distance slightly less than the space between the projections. This contrasts strongly with the plate, which depicts a less extensive but deeper notch embracing the first lateral line scale.

A feature not noticed in the original account (nor indeed in that of any member of the family dealt with in the *Endeavour* report but probably present, being developed in our second Tasmanian species) is the curious conformation of the ventral surface between the point, about level with hind border of orbit, at which the branchiostegal membranes curve in to become subparallel (continuing forward without fusion) and a median point shortly beyond the ventral bases. The subtriangular isthmus proper, a little longer than wide and barely convex transversely, is immediately followed behind by a distinct platform virtually flat throughout though with some indication (possibly post-mortem) of mesial depression, its anterior border linear where it is wholly contiguous with the isthmus, the lateral borders barely convex in (a) slightly concave in (b) in the anterior one-fourth thereafter somewhat convex, with greatest width, about two-fifths of the length, found at or behind the middle. The whole platform is very clearly defined, being almost at right angles to the lateral surfaces, its lines of junction with them sharply drawn, barely rounded. After maintaining its general width to level of insertion of ventrals it continues between them as a short broad tongue the scales on which have the appearance of overlapping some larger darker colored ordinary midventral scales. It is chiefly yellowish with some slight median dark grey, contrasting strongly both with the isthmus which presents a network of whitish and plumbeous and with the flanks which are here (in the preserved material) silvery.

Between the interpelvic process and the vent the ventral surface takes the form of a narrow flattish strip, clearly delimited throughout its length, of very dark grey, indicating the location of the intestine; in some parts this is discernible beneath the integument as a yellow or slightly greenish yellow tube marked with small regularly disposed sharply defined black dots.

Aspects of form

(a) Dorsal spines. These vary in this species from four to five, the latter number being present in both our specimens (spines in (b) damaged). In (a) the spine lengths are 6.0 9.6 13.0 15.9 16.7 mm or 86 138 187 228 240 *TLs* units; if all the log lengths are plotted on the logs of the spines' serial numbers the best straight line yields t 18.729 ($P < 0.001$). However, the increase in length of the 5th over the 4th spine is less than that expectable from the general line trend of the first four spines, which as a restricted set give a t value, 265.361 of much greater magnitude (even with 1 d.f. fewer). Both equations are set out below (in each case $P < 0.001$).

Log L = 0.6624 log N + 1.9410; estimated lengths, *TLs*, 87 138 181 219 254.

Log L = 0.7048 log N + 1.9325; 86 140 186 227.

(b) Anal spines. Presenting a common pattern, the lengths of the spines are collinear in a loglog context when plotted on their serial numbers.

Log L = 1.6662 log N + 1.3596; t 412.450**; estimated (measured) lengths, *TLs*, 23(23) 73(72) 143(144).

Log L = 1.6459 log N + 1.3509; t 206.459**; 22(23) 70(69) 137(138).

(c) Ventral rays. In (a) the spine is damaged, in (b) it measures 5.8 mm or 82 *TLs*, the rays in sequence from it 13.0 13.4 12.5 11.0 9.6 mm or 183 189 176 155 135 *TLs*. In conformity with a plan frequently encountered the plot of the logarithmic lengths of rays {1 2 3 4 — 1 farthest from spine} falls linear on logs {1 2 3 4}.

Log L = 0.2433 log N + 2.1273; t 43.076***; estimated lengths, *TLs*, 134 159 175 184.

Family Soleidae

Genus *ZEBRIAS* Jordan & Snyder, 1890

Zebrias Jordan & Snyder, 1890, p.38. Type-species, *Solea zebrias* Temminck & Schlegel.

Zebrias fasciata (Macleay, 1882)

Synaptura fasciata Macleay, 1882, p.14. Type-locality: Port Jackson.
Synaptura fasciata: Waite, 1899, p.126, pl.31: McCulloch 1916, p.61, pl.8, fig.2 and 1929, p.285.
Brachirus fasciatus: Norman, 1926, p.295.
Zebrias fasciatus: Munro, 1957, p.71, fig.494.
Zebrias fasciata: Scott, 1975, p.162 and 1976, p.178.

Tasmanian occurrence

This fish does not appear in any Tasmanian faunal list, the only sole there reported being a member of the Cynoglossidae, *Paraplagusia unicolor* (Macleay, 1881), first included in the first list of Lord (1923) (a footnote mentions it was reported from the northeast coast by the writer's father). The present species was first recorded from Tasmanian waters by the writer (Scott 1975, p.162), a detailed series of observations being made on an example, *Ls* 131, from between East Sandy Cape and Thirty Day Island (Q.V.M. Reg. No. 1973/5/109) and an example *Ls* 96, from off Prime Seal Island, Furneaux Group, Bass Strait (Q.V.M. Reg. No. 1974/5/38). Later (1976) a specimen, *Ls* 140, taken off St Helens, east coast, was reported (Q.V.M. Reg. No. 1975.5.156). Two additional examples here noted exhibit unusual features.

Material

Two specimens, (a) *Ls* 109 *Lt* 118 (b) *Ls* 114.5 *Lt* 123, collected by Mr J. Shea at Goose Island, Furneaux Group, Bass Strait in May 1980 (Q.V.M. Reg. No. 1980/5/63).

Remarks

D. 87 78, A. 68 68, V. 4 4: these fin counts are in accord with those given in the Handbook (Munro 1957, p.71). Of two lateral line counts that for (a), 98, falls just outside, that for (b), 96, just within the Handbook range of 92-96. Some proportions (Handbook values in parentheses): head in standard length 5.45 5.87 (6) , maximum depth 2.73 2.60 (2.5). Eyeball in head 4.8 4.8 full eye 4.0 2.8 ("eye" 4).

The caudal is somewhat differently represented in figures by Waite (1899) and McCulloch (1916); in the latter the free margin of the fin extends but little beyond the curve formed by continuation of the dorsal and anal and is broadly rounded, whereas in the former it has more the appearance of a separate structure and is bluntly pointed. The second condition was found to characterize out earlier material (1975, p.164), but in both the present individuals the outline of the caudal is even more fully assimilated to the outlines of the other fins than is the case in McCulloch's figure, the combined border being barely if at all resolvable into separate components, and being boldly rounded behind.

Two unusual features may be noted. While closely set moderate-sized cirri normally occur along upper and lower profiles of head and margin of gill opening, and also cover most of the undersurface of the head, in (b) those on the dorsal profile extend back to an arc joining the end of the mouth to junction of the gill cleft and the profile, and a few

are more or less similarly disposed along the ventral profile, but the whole of the rest of the head is without any cirri; in (a) only three or four minute cirri, difficult to detect, occur on either profile, and no others at all are to be found. In both individuals the typical pattern of cross-bars (here 20+, Handbook 22-24, most narrower than their interspaces) is present, but (b) presents some unusual additional markings — two well defined rounded dark spots 7-8 mm in diameter shortly in advance of the middle of the standard length, one near the ventral border the other just above the midlateral line; two similar spots half the size, both on the upper half of the side, just in front of and just behind the nearer large spot.

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PAPERS AND PROCEEDINGS OF

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Edited by M. R. Banks and S. J. Smith

and Published by the Society

Hobart, Tasmania

August 1984

Volume 118

NATIONAL MUSEUM
25 OCT 1984
OF VICTORIA

A. B. CAUDELL, Government Printer, Tasmania

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President

His Excellency the Governor of Tasmania
Sir James Plimsoll

Vice Presidents

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Dr J.E.S. Townrow

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Mr A.V. Brown
Mr J.D. Goard
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Dr M.R. Banks

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NATIONAL MUSEUM
25 OCT 1984
OF VICTORIA

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ROYAL SOCIETY OF TASMANIA

ANNUAL REPORT FOR THE YEAR 1983

The Council has the honour to present to members the following report on the activities of the Society during the year.

COUNCIL AND OFFICE BEARERS

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Honorary Auditor
Mr R.J. Dwyer

Honorary Editor
Dr M.R. Banks

Honorary Assistant Editor
Dr S.J. Smith

THOMAS EDGAR BURNS, OAM

Thomas Edgar Burns died in Launceston on 10 June 1983, aged 78. Mr Burns joined the Society in 1951 and was elected to the Northern Branch Council in 1959. He served the Northern Branch as Vice-Chairman, Chairman and Secretary. In 1978 he was elected an Honorary Life Member.

The Council places on record its appreciation of his long and dedicated service to the Society.

PRESIDENT

Sir James Plimsoll took the Chair, as President of the Society, at the Annual General Meeting in March and at the General Meeting in November. He also took the Chair at a General Meeting of the Northern Branch in July.

NATIONAL MUSEUM
25 OCT 1984
OF VICTORIA

R.M. JOHNSTON MEMORIAL MEDAL

At the General Meeting in April, the R.M. Johnston Memorial Medal was presented to Dr A.G. Fenton. Previous recipients have been:

1923	Sir T.W. Edgeworth David	1948	Professor T. Griffith Taylor
1925	Professor F. Wood-Jones	1950	Professor J.T. Wilson
1929	Dr R.J. Tillyard	1957	Professor F. Walker
1934	Professor W.J. Dakin	1959	Sir Edmund Hillary
1937	Sir David Rivett	1977	Professor S.W. Carey
1946	Professor L.H. Martin		

CLIVE LORD MEMORIAL MEDAL

At the General Meeting in November, the President presented the Clive Lord Memorial Medal to Mr N.J.B. Plomley. Previous recipients have been:

1936	Professor L.F. Giblin	1960	Emeritus Professor V.V. Hickman
1939	Professor J.B. Cleland	1966	Dr Winifred Curtis
1947	Dr H. Thompson	1973	Dr W. Bryden
1951	Professor J. Burke	1977	Dr E.R. Guiler
1958	Mr P.G. Law		

ANNUAL MEETING

At the Annual Meeting on 1 March, Dr A.G. Wallace retired as Vice-President and Dr E.A. Colhoun and Dr J.E.S. Townrow as Members of the Council. The following were elected:

Vice President	Dr J.E.S. Townrow
Members of Council	Dr P.G. Quilty
	Dr S.J. Smith
Honorary Secretary	Mr D.R. Gregg
Honorary Treasurer	Mr T.A.H. Knight

REVISION OF RULES

The Rules, as amended at the 1981 Annual General Meeting, and further amended at a Special Meeting held on 7 September 1982, were distributed to members.

MEMBERSHIP

The membership is 464, the same as 1982, and is made up as follows:

	Northern Branch	Total
Honorary Life Members	2	6
Life Members	9	34
Ordinary Members receiving the Papers and Proceedings	70	279
Ordinary Members not receiving the Papers and Proceedings	71	126
Associate Members	16	19
	168	464

COUNCIL MEETINGS

The Council met four times during the year with Mr B.A. Pike and Mr P.G. Webb representing the Northern Branch on the Council.

BANKS MEMORIAL LECTURE

The Council continued to pursue the proposal that the bicentennial of the European settlement of Australia in 1988 be marked by a lecture honoring Sir Joseph Banks. The Royal Society, London, has supported the proposal.

ROYAL SOCIETY ART COLLECTION

The Council has discussed the responsibilities of the Society to its art collection which since 1965 has been on loan to the Tasmanian Museum and Art Gallery. The collection consists of 683 items, including 285 watercolours and 172 pencil drawings, most of which are of great importance to the heritage of Tasmania.

The Council has agreed to give its full support to the Trustees of the Tasmanian Museum and Art Gallery in any application they may make for funds to conserve and maintain the collection.

PUBLICATIONS

Volume 117 of the Papers and Proceedings was published in August 1983. It contained 15 papers, by 26 authors and totalled 202 pages.

The Society is once more indebted to Dr Banks for his dedicated and expert work as Honorary Editor. Dr S.J. Smith continued as Honorary Assistant Editor.

LIBRARY

The continuing steady use of the Library underlines its importance as a reference source for Royal Society members, University staff and students, and researchers from the general community. During the year 380 visitors signed the users' register. Of special note was the increase in interlibrary loan requests to 230; these were sent to other libraries in Australia and overseas through the University's Interlibrary Loan Service.

The Library receives 686 journals currently, from its 291 exchange partners, and subscribes to 13 additional titles. During the year an exchange was established with the Rijksmuseum Van Natuurlijke Historie, Netherlands, for their Zoologische Medelingen.

During the year the Library received the following donations:

Bremner, J. (comp.): WELLINGTON'S NORTHERN SUBURBS, Onslow Historical Society, 1983.

Campbell, N. & Smellie, R.M.S.: THE ROYAL SOCIETY OF EDINBURGH 1783-1983: THE FIRST TWO HUNDRED YEARS, Royal Society of Edinburgh, 1983.

Morton, J.: THE WHALE'S WAKE, University of Otago Press, 1982.

Simpson, R.P. & Holmes, J.H. (Eds): MAN AND THE ENVIRONMENT: REGIONAL PERSPECTIVES, 2nd ed., Longmans, 1983.

No changes were made to loan conditions. The monograph collection remains a reference collection, loans of one week's duration to be arranged only in special circumstances and at the Librarian's discretion. Bound periodicals continue to be available for one week's loan to Society members, University staff and Higher Degree and Honours students and during the year 174 items were borrowed.

The University Bindery's vigorous binding programme of past years meant that most of the very long and higher risk titles have been bound. Thus binding was conducted at a reduced level, 900 volumes being bound during the year.

No facilities existed in the Library to maintain the map collection and maps were starting to deteriorate. On 11 August the Council of the Royal Society approved of the transfer of the map collection to the Geography Department of the University and this was completed in December. The transfer of historical maps to the University Archives was also completed.

In February 1983 Stefan Petrow became Librarian. From July to the end of November, while Mr Petrow was temporarily seconded to another section of the University library, Mrs Gaye Thavisin was Acting Royal Society Librarian. Mr Petrow returned in December. Mrs Pam Wendell-Smith continued to be employed on a part-time basis for one and a half days each week.

LECTURES

The following lectures were given at General Meetings during the year:

March	"The University - Past, Present and Future."	Professor A. Lazenby, University of Tasmania
April	R.M. Johnston Memorial Lecture - "Cosmic Rays."	Dr A.G. Fenton, University of Tasmania
May	"Waste wood." - mini-symposium	Mr B. Graham, Tasmanian Conservation Trust and Dr M.L. Higgs, Forestry Commission of Tasmania
June	"Macquarie Island Wildlife Sanctuary."	Mr D. Rounsevell. Tasmanian National Parks and Wildlife Service
July	"Cape Grim Base Line Pollution Station."	Dr R. Francey, Base Line Air Pollution Station
August	"The Origin of the Australians."	Dr A. Thorne, Australian National University
September	"What about human ecology? New ideas on environmental causes of disease."	Dr V. Von Witt
October	"Port Arthur and the Burra Chapter. A new approach."	Dr B.J. Egloff, Tasmanian National Parks and Wildlife Service
November	Clive Lord Memorial Lecture - "Pre-Settlement Exploration of Tasmania and the Natural Sciences."	Mr N.J.B. Plomley

Two excursions were held. On 17 September, a tour of forests of the Triabunna district was organised by the Forestry Commission. On 12 November, Dr B.J. Egloff of the National Parks and Wildlife Service showed members something of the work being done by the Port Arthur Conservation Project.

NORTHERN BRANCH

Chairman	Mr B.A. Pike
Vice-Chairman	Mr D.G. Hannan
Past Chairman	Mr R.E. Ward
Council Members	Mrs G.M. Morris
	Mr A.T. Orr
	Mrs P. Ratcliff (resigned 17 November)
	Mr J.H. Chambers
	Dr D. Hamilton
Honorary Secretary	Mr P.G. Webb
Honorary Treasurer	Mr K.E.J. Robinson
Honorary Auditor	Mr J.D. Abey
Branch Representatives on Council	Mr B.A. Pike
	Mr P.G. Webb

The Branch Council met four times, the principal business being the celebration of the Centenary of Instrumental Seismology in Australia, and the provision of a speaker's lectern as a memorial to the late T.E. Burns.

The following lectures were given at General Meetings:

March	"Bishop Mercer in Tasmania 1906-1914."	Dr R.P. Davis, University of Tasmania

April	"The importance of the wreck of the *Sydney Cove*."	Mrs Shirley Lester, Queen Victoria Museum
May	"Reflections on Antarctica, or why are seals' kidneys like a bunch of grapes?"	Mr P. Vardy, Tasmanian College of Advanced Education
June	"Cosmic Rays" (repeat of the Johnston Mémorial Lecture).	Dr A.G. Fenton, University of Tasmania
July	"Stone and a sense of place."	Dr E.V.R. Ratcliff,
August	"The origin of the Australians."	Dr A. Thorne, Australian National University
September	"Conservation at the crossroads: new perspectives."	Dr A. Osborne, Tasmanian College of Advanced Education
October	"The emergence of federation architecture in Launceston."	Robert and Miranda Morris-Nunn
November	"The Beattie Collection."	Mrs M. Tassell, Queen Victoria Museum
December	Members' Night: "A little of Banjo Patterson." "A voyage with my father."	Mr R.E. Ward Mr P.G. Webb

The Branch also supported actively the presentation of three other important lectures:

March	The Mead-Smith-Von Stieglitz Lecture
August	The Eldershaw Memorial Lecture - presented by the Tasmanian Historical Association. "Restoration at Port Arthur" by Mr Peter Spratt - presented by the Australian Federation of University Women and the National Trust.

On 4 November a one-day seminar was held to commemorate the centenary of the first use in Australia, by Mr A.B. Biggs in Launceston, of instruments built specially to measure earth tremors. The seminar was entitled *The Centenary of Instrumental Seismology in Australia* and was first proposed by Dr R. Underwood. Three speakers, two from interstate and one Tasmanian, gave papers on Biggs' work in astronomy and on seismology in Australia, and a commemorative dinner was held. Although the attendance was small the seminar was accounted a success; and the Branch welcomed the opportunity to commemorate a Launceston pioneer in the field.

The papers read at the seminar were published under the title *Earth Tremors* and are available at $5.00 from the Honorary Secretary of the Branch.

The Branch Council decuded to commemorate the work of the late T.E. Burns by obtaining a speaker's lectern. Students in the course in Applied Design Skills (Wood) at the Tasmanian College of Advanced Education were invited to enter designs for a lectern, the winning design to be commissioned and two other prizes to be awarded. Members were asked to contribute funds to meet the costs involved.

The lectern was completed in time for use at Members' Night, when the designer/builder Mr C.J. Sly, spoke about his design and the Tasmanian timbers used in its construction. The whole cost of the project has been met by donations from more than fifty members.

As a result of discussion at the last Annual General Meeting, Council investigated other places available in the city for regular meetings, but has not been able to find a hall or room with comparable facilities better placed than the Museum theatrette.

NOMINEES TO OTHER BODIES

The Council re-elected Dr M.R. Banks and Mr A.R. Neilson to the Board of Trustees of the Tasmanian Museum and Art Gallery. They report on the year's activities:

The 1983 State Budget provided $1 000 000 to the Tasmanian Museum and Art Gallery, an increase of 30% on the previous year. The Trustees, while appreciative of the increase, were disappointed that the grant remains substantially below their needs. The increase will enable some progress to be made on essential maintenance and upgrading of the collections, facilities and displays.

Funds have not permitted any additions to the permanent staff. However, 13 temporary staff have been employed with funds provided through the Commonwealth Government as follows:

Australian Biological Resources Study (Dept Home Affairs and Environment)	4 persons
Wage Pause Programme	8 persons
National Employment Strategy for Aboriginals	1 person

The development of the Museum and Art Gallery on its central site in Hobart was approved by Cabinet in February 1983. A submission is in preparation for the Parliamentary Standing Committee on Public Works and it is hoped that work will restart on the renovation of the Commissariat Store Building at 40 Macquarie Street in 1984.

Tenders have been called by the Department of Construction for alterations to the West Coast Pioneers' Memorial Museum at Zeehan, including the renovation of the first floor of the Post Office building.

Welcome support during 1982-83 has come from various organisations in Tasmania. Substantial financial contributions totalled $28 000, as follows:

$14 000 from Tasmanian Teachers Credit Union for Money Room
$5 000 from *The Mercury* for Fitzwilliam Exhibition
$3 000 from Charles Davis Group for an Oliffe Richmond sculpture
$3 000 from Comalco for an Oliffe Richmond sculpture
$3 000 from Electrolytic Zonc Co. for Herbarium Library

These generous donations provided funds for special projects, exhibitions and acquisitions which otherwise would not have been possible.

The Money Room, displaying the numismatic collection, was opened by the Governor of Tasmania on 18 May 1983. Sponsorship by the Tasmanian Teachers Credit Union has enabled the coins to be displayed in a secure, safe and attractive setting.

The Art Bulletin of Tasmania 1983, the first of a projected series of annual volumes, was launched by the Governor on 26 July 1983. The Bulletin was initiated and edited by Mr Hendrik Kolenberg, Curator of Art.

A book, *The Aboriginal People of Tasmania* by Ms Julia Clark, Curator of Anthropology, was published by the Museum and Art Gallery and launched by Mr Roy Nichols, Chairman of the National Aboriginal Conference, on 20 December 1983. Mr Nichols also opened new displays dealing with the Tasmanian Aboriginal people.

During the 1983 year, 144 877 people were counted visiting the Tasmanian Museum and Art Gallery, compared with 101 552 in 1982. The showing of the America's Cup attracted record crowds and over 99 000 people visited the Museum and Art Gallery during the 14 days it was on show from 26 December 1983 to 8 January 1984. The attendance at the West Coast Pioneers' Memorial Museum was estimated at 112 5000 for the 1982-83 financial year.

Dr Banks was re-elected Chairman of Trustees.

Dr Jocelyn E.S. Townrow continued as the Council's nominee on the Board of Trustees of the Royal Tasmanian Botanical Gardens. She reports on the year's activities:

> 1983 was a good year for the Royal Tasmanian Botanical Gardens, with progress visible in both completed and initiated projects, and with continued maintenance of the high standard of floral displays, despite difficulties associated with the unusually dry conditions of the continuing drought.

The Gardens retained their popularity with the public though the number of visitors (203 806) represented a drop of 9.7% on the previous year's total. This drop closely parallels the downturn in the tourist industry during the year.

State Government funding increased in line with inflation to $740 000 of which $454 000 was for wages and salaries. Over and above this funding, special grants were obtained for the sewerage scheme and for the toilet for the Easy Access Garden. The Trustees viewed with concern an excess Water Rate of $15 000 and in an effort to cut water waste and costs, sought advice from the Mines Department regarding the possible availability of bore water in the Gardens and assistance from the Metropolitan Water Board in locating leaking pipes. From the results of these investigations, it is envisaged that the whole water reticulation system will have to be replaced in the near future. Indoor plant decorations loaned to Government Departments by the Gardens represent a further hidden drain on the budget of $7 360.

The Museum and Education Centre which attracted about 11% of Garden's visitors was closed for 3½ months. It re-opened on 1 September after extensive reconstruction involving the Board Room, and the Economic Plants Room. The latter was remodelled from two rooms which are now joined through a brick archway. The new displays have received very favourable comment, and reflect the dedication and inspiration of the Information and Education Officer, Alan Gray. 1 200 children have visited these displays despite the bleak, cold winter and spring weather. In response to visitors' requests and with the invaluable cooperation and assistance of about 40 Friends of the Gardens, the Museum opening hours are to be changed in the new year to 12 noon - 4.00 p.m.

Visitors have appreciated the new Locality Map at the Gardens Entrance and much greater use has been made of the Let's Talk About the Gardens leaflet and the Huon Pine leaflet.

Completed projects include the new sewerage scheme, restoration of the Eardley Wilmot Wall, and the most attractive classical Herb Garden beside the Arthur Wall. An archaeological investigation of the Arthur Wall prior to restoration has been financed by the Office of the National Estate.

Further progress has been achieved with the Easy Access Garden. A disabled person has been in attendancd working as a gardener for several months on a grant of $1 120 from outside funds. Hobart Rotary are considering supplying a small transport bus for disabled people, and completion of the Glasshouse is now in hand.

The Restaurant has had a "face lift" with alterations both inside and outside with improved seating space and kiosk facilities. A new cactus house has been constructed on the northern face of the Tropical House and in cooperation with the Cactus Society of Tasmania, is being landscaped along with an outside Cactus Garden. Both will be most interesting additions to the Gardens' comprehensive floral displays.

The Gardens have bebefited from the Government Wage Pause Programme with funding to support the employment of 11 people, two to help develop the Museum and Education Centre displays, four for outside gardening and five for the redevelopment of the Camelia and Rhododendron Garden. Thanks to this extra help in the Gardens, it has been possible to replace a retiring gardener with a part-time Plant Recording Officer, Mrs S. Wells. The Trustees are most pleased with this timely appointment, because the approaching retirement date of our Landscape Architect, Dr Vitesnik makes it imperative that the information he has about the plants in the Gardens be recorded.

The Trustees are also delighted to have Government permission and support to go ahead with planning for the new Depot Area and No.4 Glasshouse, both now in hand. The Department of Construction is to take over the reconstruction of the footpaths. The new toilets should be completed by May 1984.

The superintendent, Mr May, Dr Vitesnik and Mr Gray are to be commended on two excellent displays at the Hobart and Launceston Agricultural Shows, both of which gave the Gardens excellent publicity and occasioned much enthusiastic comment. At Launceston, culinary and medical herbs were featured, while at Hobart, the theme was

on economic plants. This display formed the basis for the ongoing display of economic plants in the Gardens' Museum.

ACKNOWLEDGEMENTS

The Council is grateful for help generously given by many individuals and organisations. In particular, the lecturers, the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery, the Queen Victoria Museum and Art Gallery, the National Parks and Wildlife Service, and the Forestry Commission of Tasmania are specially thanked for their help and cooperation.

ROYAL SOCIETY OF TASMANIA

STATEMENTS OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31 DECEMBER 1983

GENERAL ACCOUNT

Balance brought forward		2 666.53	Stationery		204.78
			Insurance		176.84
Subscriptions			Attendant's fees		485.15
			Secretarial fees		1 343.73
1 @ $200	200.00		Post box rental		88.00
262 @ $12	3 144.00		Postage and freight		949.52
124 @ $8	992.00		Photocopying		33.07
18 @ $5	89.00		Subscriptions		465.17
Other years	287.00		Northern Branch		800.00
		4 712.00	Repairs and maintenance		193.25
			Federal debit tax		7.55
Interest		4 046.23	Telephone		9.84
Rent		314.11	Lecture expenses		325.30
Donations		5.46	Subscription refund		10.00
Sales of publications and			Symposiums		596.00
Papers and Proceedings		1 134.71	Printing -rules and reports		656.58
University subvention		1 600.00	Honour Board		135.00
Symposium		96.00	Miscellaneous		64.74
					6 544.52
			Typing of Papers and Proceedings		3 018.70
					9 563.22
			Balance carried forward		5 011.82
		$14 575.04			$14 575.04

PAPERS AND PROCEEDINGS ACCOUNT

Balance brought forward	520.51	Balance carried forward	1 038.77
Interest	518.26		
	$1 038.77		$1 038.77

ACCUMULATION ACCOUNT

Balance 1 January 1983			56 164.83
Deduct: Net transfers to Trust Funds		1 925.58	
Net increase in advance subscriptions		122.00	
Net increase in valuation of publication for sale		895.70	
			2 943.28
			53 221.55
Add: Increased cash at bank			3 142.12
Balance 31 December 1983			$56 363.67

ROYAL SOCIETY OF TASMANIA

AUDITED BALANCE SHEET AS AT 31 DECEMBER 1983

1982			1983	1982		1983
56 164.83	Accumulation Funds		56 363.67	33.00	Cash on hand	33.00
88.00	Subscriptions in advance		210.00		Cash at bank:	
	Trust Funds:			2 666.53	- General account	5 011.82
1 568.15	- Clive Lord Memorial Fund	1 724.59		520.51	- Papers & Proceedings Account	1 038.77
2 605.38	- A.N. Lewis Memorial Fund	2 894.51		160.09	- Clive Lord Memorial Fund	278.78
1 163.56	- Morton Allport Memorial	1 304.53		244.51	- A.N. Lewis Memorial Fund	404.39
477.36	- A.A. Clark Bequest	524.56		860.00	Mortgage Loan	860.00
3 210.99	- Joseph Milligan Bequest	3 551.62			Commonwealth Treasury Bonds &	
1 714.51	- R.M. Johnston Memorial Fund	1 914.07		29 900.00	Inscribed Stock (at cost)	29 900.00
754.53	- Henry Oliver Bequest	838.68		7 000.00	Interest Bearing Deposits	7 000.00
1 733.16	- W.H. Hudspeth Memorial	1 923.94		15 000.00	Library (at valuation for insurance)	15 000.00
2 645.07	- Life Membership Fund	3 121.79		15 740.90	Publications (at selling prices)	14 845.20
			17 798.29			
$72 125.54			$74 371.96	$72 125.54		$74 371.96

Papers and Proceedings of the Royal Society of Tasmania, Volume 118, 1984

(ms. received 1.III.1984)

THE GLACIAL DIVERSION OF THE QUE AND BULGOBAC RIVERS, WESTERN TASMANIA

by Eric A. Colhoun and Paul Augustinus
Department of Geography, University of Tasmania

(with one text-figure and one plate)

ABSTRACT

COLHOUN, E.A. and AUGUSTINUS, P., 1984 (31 viii): The glacial diversion of the Que and Bulgobac Rivers, western Tasmania. *Pap. Proc. R. Soc. Tasm.*, 118: 1-4, pl.1. ISSN 0080-4703. Department of Geography, University of Tasmania, Hobart, Tasmania, Australia.

Glacier ice diverted the courses of the upper Que and Bulgobac Rivers from a direct route to the Pieman River through the Que Gorge to the Huskisson River. The diversion probably occurred in the Early Pleistocene but the drainage pattern established was maintained and perhaps accentuated by further glaciation during the Middle Pleistocene. The modern drainage pattern is a palimpsest of that which existed by late Middle Pleistocene times.

INTRODUCTION

Repeated glaciation during the Quaternary had profound effects on the morphology of the West Coast Range of Tasmania. The small ice caps, with their reticulate pattern of outlet glaciers in the deep valleys west of the range, not only produced erosional and depositional glacial landforms but also modified the directions taken by some elements of the preglacial drainage systems. The most notable example is the diversion of the Que and Bulgobac Rivers from their former course via the Tramway and Farm creeks to the Pieman River through the Que Gorge to the Huskisson River. A similar diversion of John Lynch Creek from the Marionoak to the Huskisson occurred at the head of the Marionoak River, and of the upper part of the Boco Creek from Tramway Creek to the present Boco Creek (figs 1A and B).

An example of glacial diversion of drainage has been described from Cradle Valley, where last glaciation ice caused a northeasterly flowing strike-aligned stream to be diverted northwards in a deep gorge across a ridge (Colhoun 1980). However, no diversion of drainage associated with pre-last glacial age ice has been described from Tasmania, although Reid (1918) considered that the flat plain of the Boco Valley marked a preglacial river course that commenced at the confluence of Farm Creek with the Pieman River and flowed northwards. Reid regarded this stream as having come from the Mackintosh Valley.

Recent investigations of the glacial geomorphology of the area between Bulgobac and the upper Pieman Valley suggests that the evolution of the modern drainage pattern (fig. 1A) from the reconstructed preglacial drainage pattern (fig. 1B) probably occurred as the result of diversion during at least two periods of glaciation (fig. 1C) that preceded the last glaciation. The probable sequence of events and drainage evolution is now interpreted with regard to the ice limits inferred from the glacial deposits.

THE BOCO-BULGOBAC-QUE-MARIONOAK RIVER AREAS

The relatively broad, predominantly flat-floored depression that extends northwards from the Pieman River and is occupied by Farm Creek in the south, Tramway and upper Boco creeks in the middle, and Animal and Bulgobac creeks in the north is separated from the middle section of the Que River by a low ridge at 520 to 560 m elevation. The surface of this depression descends southwards from 520 to 160 m in 15 km. It is filled with thick glacial till and outwash deposits that overlie rhyolitic tuffs with intercalated sediments of the Cambrian Mount Read Volcanic Formation. To the east the depression is bounded by a

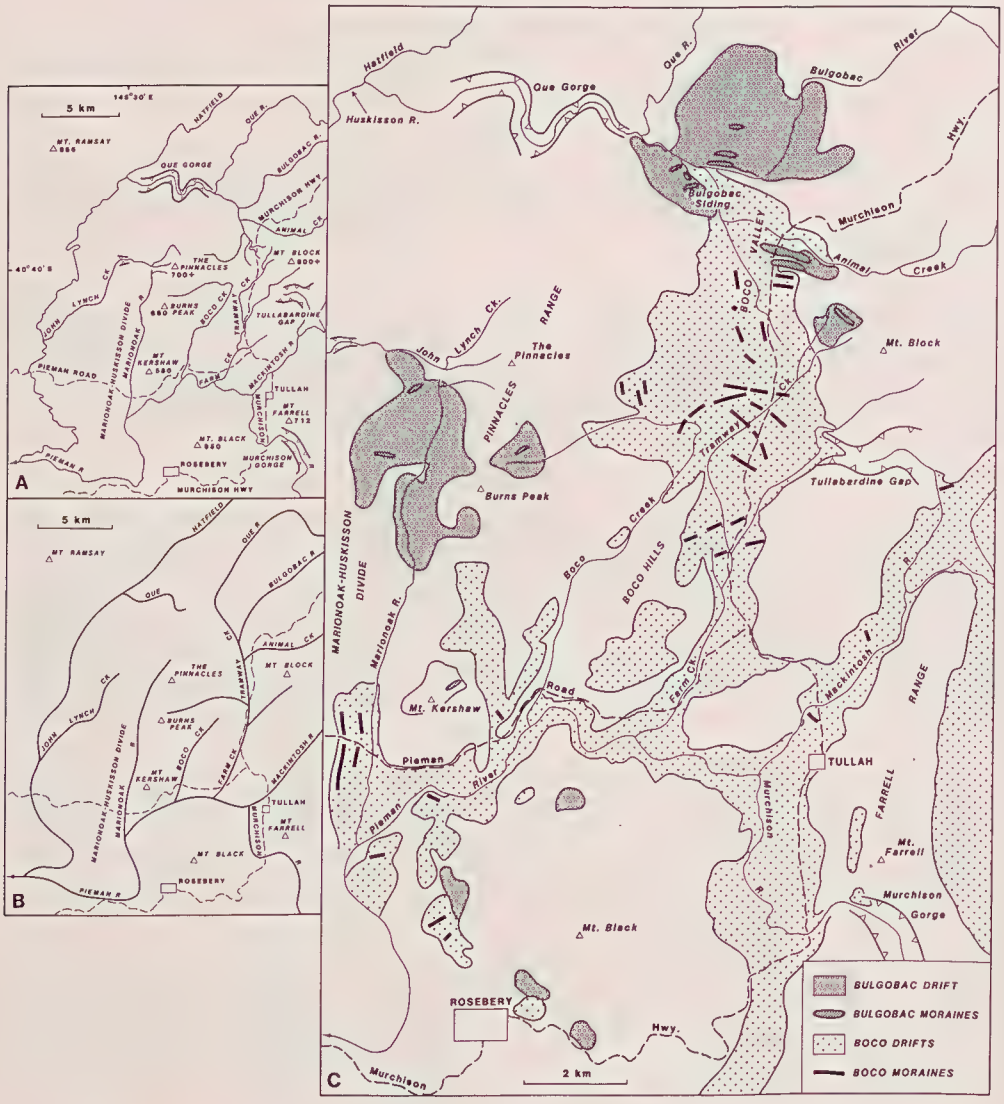

FIG. 1 - A: Modern drainage pattern of the Boco-Bulgobac-Que River region.
B: Reconstructed probable preglacial drainage pattern.
C: Deposits of the Bulgobac and Boco Glaciations.

northeast strike-oriented ridge formed mainly of volcanics, the highest point of which is Mount Block (800+ m). The ridge is breached only by the 300 m-deep glacial diffluence of Tullabardine Gap. To the west the depression is bounded by the Pinnacles Fault, and the northeasterly trending strike-ridge that includes Burns Peak (660 m) and the Pinnacles

(700+ m), which separate it from the Marionoak Valley. This ridge consists mainly of volcanic rocks.

The strongly trellissed drainage pattern dominated by the NE-SW strike-oriented subsequent streams, the southward descent of the rock floor of the Boco Depression as determined from drilling and resistivity surveys made by the Electrolytic Zinc Co., Rosebery, and the apparently young 80-200 m deep incised course of the Que Gorge (plate 1), indicates that the preglacial drainage of the area resembled that of figure 1B, and was tributary to the Pieman River. The preglacial Tramway-Farm creek system drained southwards rather than northwards as suggested by Reid. The preglacial age of this deep valley is indicated in bore holes, where up to 5 m of weathered volcanic bedrock has been encountered beneath the glacial drift. This indicates that a long period of subaerial weathering occurred prior to glacial deposition, and that the bedrock form of the valley was similar to present.

PLATE 1 - The intake to the Que Gorge below the confluence of the Que and Bulgobac rivers.

The Marionoak Valley and the ridge to the west that separates it from the Huskisson Valley are also formed predominantly of Cambrian volcanic rocks. The upper part of the John Lynch Creek drains southwestwards towards the head of the Marionoak River but at about 500 m elevation it turns abruptly westwards and drains through a small gorge into the Huskisson Valley leaving the upper part of the Marionoak beheaded. Similarly, a tributary that flowed eastwards towards Tramway Creek from north of Burns Peak appears to have been diverted southwestwards along Boco Creek.

GLACIATION AND DRAINAGE DIVERSION

Field mapping of the glacial landforms and deposits by Augustinus in the area revealed the occurrence of at least two glaciations that preceded the last glaciation. The older glaciation, referred to as the Bulgobac, is represented by highly weathered till and outwash deposits that extend at least 3 km north of the Bulgobac River in the upper Boco Valley. These deposits are up to 50 m thick and are bounded to the south by large morainic ridges that extend from Animal Creek to Bulgobac Siding (fig. 1C). Similar highly weathered till, outwash deposits, and small ridges of moraine occur in the upper part of the Marionoak Valley. Both suites were deposited by northward and northwestward moving ice from the Pieman Valley. The high degree of weathering, and the reversed magnetisation of laminated deposits associated with similar weathered glacial deposits recorded by Barbetti & Colhoun from the Marionoak-Huskisson divide in the Pieman Valley, indicate that the glacial deposits are at least as old as the Early Pleistocene.

The initial diversion of the Que and Bulgobac rivers, and Animal Creek through the Que Gorge, and the diversion of the John Lynch Creek through its small gorge to the Huskisson River, occurred during the maximum extent of ice and the initial retreat stages of the Bulgobac Glaciation (fig. 1C). The form of the glacial deposits and their thick-

ness in the Bulgobac and upper Marionoak valleys indicate that after the initial diversion the headwaters of the Que and Bulgobac rivers, Animal Creek, and John Lynch Creek were never again connected with their preglacial courses via Tramway and Farm Creeks, and the Marionoak River to the Pieman.

After a long interval, but prior to the last glaciation the Boco Valley was again glaciated by ice that flowed northwards from the Pieman and westwards through the Tullabardine Gap. This Boco Glaciation may have occurred as two stages, Boco I extending to Animal Creek and Boco II extending to Boco Railway Siding. The till and outwash deposits occur on the floor of most of the Boco Valley and in the Pieman Valley as far as the two moraines that occur 500 m west of the Marionoak River and adjacent to the Pieman Road. Ice of the Boco Glaciations did not extend to the upper part of the Marionoak Valley. There are numerous moraine ridges in the middle and upper Boco Valley. The ice that deposited these poured a great sheet of outwash gravels northwards towards the Bulgobac River and the intake to the Que Gorge (plate 1). This ice, and its deposits, which are up to 48 m thick near Boco Railway Siding and 1 km to the north (Electrolytic Zinc Co. drilling records), have maintained the diverted courses of Animal Creek and the Bulgobac River through the Que Gorge. Thick glacial gravels have diverted the tributary west of Tramway Creek southwestwards into the head of the Boco Creek, which occupies a former large meltwater channel. The deposits associated with the Boco Glaciations are beyond the range of ^{14}C assay, are moderately weathered, and appear to be of pre-last interglacial age. Therefore, it would appear that the pattern of glacial drainage that existed at the end of the Boco Glaciation (probably the penultimate glaciation) was the pattern inherited by the modern streams.

CONCLUSION

From the field evidence related to the extent of former glaciation it can be concluded that the Que and Bulgobac rivers, and Animal Creek were diverted westwards through the Que Gorge, and that John Lynch Creek was diverted westwards through a small gorge to the Huskisson River in the Early Pleistocene (>700 000 yr B.P.). The effects of the later Boco Glaciations were to maintain the diverted courses of these rivers. In addition, ice of the Boco Glaciation diverted the upper part of Tramway Creek through the Que River Gorge, and a western tributary into the head of Boco Creek during the Middle Pleistocene. There has been virtually no alteration of the drainage pattern that was formed by late middle Pleistocene times (pre 130 000 yr B.P.) during the Late Pleistocene (post 130 000 yr B.P.).

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TASMANIAN HIGH MOUNTAIN VEGETATION II - ROCKY HILL AND PYRAMID MOUNTAIN

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(with two tables, three text-figures and four plates)

ABSTRACT

KIRKPATRICK, J.B., 1984 (31 viii): Tasmanian high mountain vegetation II - Rocky Hill and Pyramid Mountain. *Pap. Proc. R. Soc. Tasm.*, 118: 5-20, pls 1-4. ISSN 0080-4703. Department of Geography, University of Tasmania, Hobart, Tasmania, Australia.

Rocky Hill and Pyramid Mountain are composed of horizontally bedded Permian to Upper Carboniferous sedimentary rocks, the nature of which has encouraged the development of fjaeldmark and nonsorted stone steps and stripes. Buried *Athrotaxis* logs in the present alpine zone, the patterns of distribution of fire-susceptible species and other evidence suggest that the area has been subject to at least two severe and extensive fires, which have resulted in landscape instability. Nevertheless, the present vegetation of the area is varied, lacking only deciduous heath and tussock grassland of the alpine subformations and having a full range from sedgeland to closed-forest in the subalpine vegetation. The species composition of the vegetation of the two mountains is most similar to that of Cradle Mountain.

INTRODUCTION

The Tasmanian high mountains possess varied floras and vegetation complexes, these variations most strongly relating to precipitation and soil characteristics (Kirkpatrick 1980, 1982, 1983). Most of the mountains with alpine vegetation (*sensu* Kirkpatrick 1982) consist of dolerite or highly siliceous quartzites and quartzitic conglomerates. However, there is a small number of mountains formed of horizontally bedded Permian to Upper Carboniferous sediments, on which there are concentrated the Tasmanian fjaeldmarks (Kirkpatrick & Harwood 1980, Kirkpatrick 1983). This paper provides a description of the fjaeldmarks and other vegetation of two of these sedimentary mountains, Rocky Hill (1160 m) and Pyramid Mountain (1250 m), both located in the wilderness between Lake St Clair and Queenstown (fig. 1). No nearby climatic data are available but mean annual precipitation certainly exceeds 2000 mm.

METHODS

All higher plant species observed were noted and/or collected during a field trip in February 1983. Nomenclature follows Curtis (1963, 1967, 1979), Curtis & Morris (1975), Curtis & Stones (1978) and Willis (1970) with the latest publication having precedence. Authors are given in table 1 (tables after references) wherever nomenclature cannot follow these authorities. Specimens are held in the Herbarium of the Tasmanian Museum and Art Gallery.

Notes were made of the occurrence and environmental relationships of species, vegetation structure and periglacial landforms. Twenty-nine 10 × 10 m quadrats were located in order to encompass the major part of the variation in alpine vegetation. All higher plant species, the dominant species, the vegetation structure and details of the environment of each quadrat were recorded.

The vegetation was mapped from field observation and interpretation of 1979 panchromatic vertical aerial photographs. Fire boundaries were obtained from earlier photographs and field evidence.

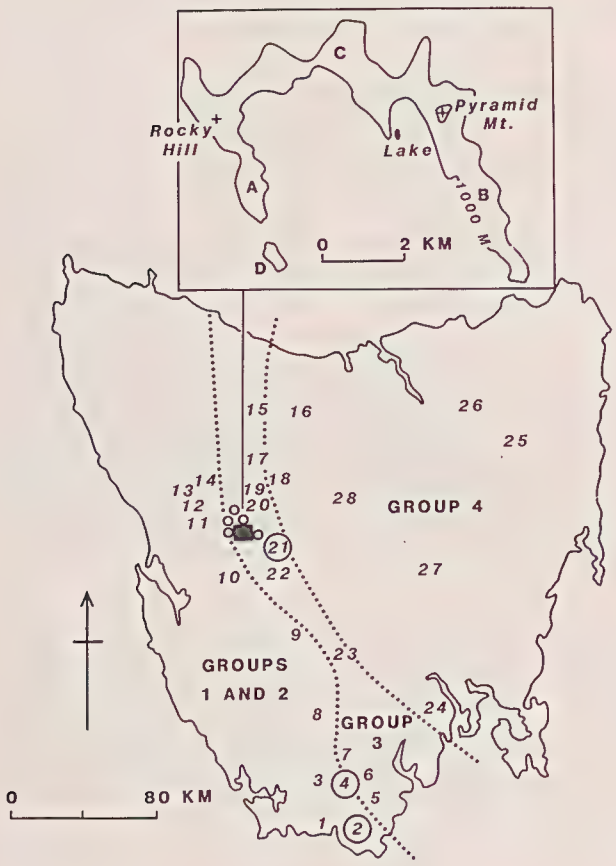

FIG. 1 - Locations of study area, the mountain flora classification of Kirkpatrick (1982), and known locations of nonsorted stone stripes and steps (large and small circles). Mountain codes:

1 Ironbound Range
2 Southern Range (including Mt La Perouse)
3 Eastern Arthur Range
4 Mt Bobs/Boomerang
5 Adamsons Peak
6 Hartz Mountains
7 Mt Picton
8 Mt Anne
9 Denison Range
10 Frenchmans Cap
11 Mt Sedgwick
12 Tyndall Range
13 Mt Read
14 Mt Murchison
15 Black Bluff
16 Mt Roland
17 Cradle Mt-Barn Bluff
18 Mt Oakleigh
19 Mt Ossa/Pelion East
20 Walled Mountain
21 Mt Rufus
22 Mt King William
23 Mt Field
24 Mt Wellington
25 Ben Lomond
26 Mt Barrow
27 Table Mountain
28 Central Plateau.

Species associations in the alpine vegetation were discriminated using the matrix-resorting methods described and justified in Kirkpatrick (1980). Structural terminology follows Kirkpatrick (1983) for alpine vegetation and Specht (1974) for other vegetation.

RESULTS

Floristic Relationships

Rocky Hill and Pyramid Mountain have highly similar alpine floras (fig. 2, table 1), that of Pyramid Mountain largely being a subset of the richer Rocky Hill flora. Pyramid Mountain lacks site conditions suitable for many of the species found in bolster heath and short alpine herbfield. It also lacks the areas of quartzite found at the lowest alpine elevations on Rocky Hill, within which were confined characteristically western species such as *Isophysis tasmanica*, *Eucalyptus vernicosa* and *Monotoca submutica*.

Both mountains belong in group 3 of Kirkpatrick (1982), the central group of floras which extends from Black Bluff in the north to Adamsons Peak in the south (fig. 1), their closest affinities being with Cradle Mountain (fig. 2). The mountains with alpine floras

least similar to those of Pyramid Mountain and Rocky Hill are those in the West Coast Range and the far east of the State, the floristic extremes within Tasmania.

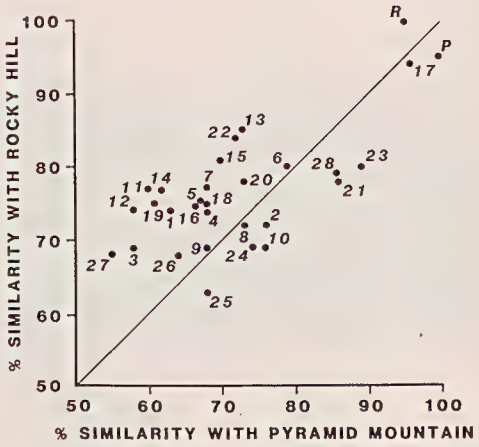

FIG. 2 - Floristic similarities between Pyramid Mountain, Rocky Hill and other Tasmanian mountains, shown in figure 1.

Species Associations

Several strong groups of species with similar distributions in the alpine vegetation of the study area are evident in table 2. The most widespread of these associations was that between *Orites revoluta, Olearia ledifolia, Epacris serpyllifolia, Poa gunnii, Euphrasia striata, Pentachondra pumila* and *Helichrysum milliganii*. The association *Richea sprengelioides-Senecio pectinatus-Exocarpos humifusus-Helichrysum backhousii-Bellendena montana* was found throughout the fjaeldmark vegetation, while the associations *Senecio leptocarpus-Agrostis venusta-Drapetes tasmanica-Plantago tasmanica* and *Coprosma nitida-Deyeuxia monticola-Dichosciadeum ranunculaceum* were confined to the fjaeldmark on the steepest slopes of Pyramid Mountain. The strong association *Microcachrys tetragona-Cyathodes dealbata-Erigeron stellatus-Carpha alpina* occurs in the gentler-sloping fjaeldmark and the vegetation with complete cover on other sampled alpine sites. The more poorly drained sites on both mountains were characterized by the association *Ewartia meredithae-Sprengelia incarnata-Baeckea gunniana-Oreobolus pumilio-Danthonia pauciflora*. The weak association *Drosera arcturi-Gleichenia alpina-Microlaena tasmanica-Actinotus suffocata-Donatia novae-zelandiae-Anemone crassifolia* was confined to some of the poorly-drained sites outside Pyramid Mountain.

Few of the above associations are similar to those revealed for Mt Picton, the Eastern Arthur Range, Mt Bobs and the Boomerang by similar analyses in Kirkpatrick (1980) and Kirkpatrick & Harwood (1980) despite these mountains having a high proportion of their alpine species in common with Rocky Hill and Pyramid Mountain (fig. 2). The degree of mountain specificity in Tasmanian alpine plant associations can only ultimately be tested by a statewide analysis of quadrat/releve data.

Fjaeldmark

Fjaeldmark is found in the study area of slopes varying from 1:1 to 1:3. The vegetation type is confined to the western slopes and the tops of hills and peaks, the slopes sheltered from the prevailing winds invariably possessing complete plant cover (fig. 3).

The flat-topped hills A and B (fig. 1) support a fjaeldmark in which there is clear evidence of the migration of individual shrubs in the same manner as has been recorded for the metasediment ridges at Kosciusko (Barrow *et al.* 1968) and the Boomerang (Kirkpatrick & Harwood 1980). All shrub species occurring within this fjaeldmark (*Epacris serpyllifolia, Richea sprengelioides, Microcachrys tetragona, Orites revoluta, Leptospermum rupestre, Cyathodes petiolaris, Cyathodes dealbata, Pentachondra pumila*) were examined and proved to layer and to have dead stems on their windward side. The rhizomatous herbs *Erigeron stellatus, Helichrysum milliganii, Senecio pectinatus, Poa gunnii* and *Oreobolus oligocephalus* also occurred in this fjaeldmark. The shrubs do not have the even distribution that occurs at Kosciusko as the uniformity of the substrate is broken by occasional bedrock outcrops, creating a tendency towards lineation. However, individual shrubs are well separated within these weak lines, their past movements being marked by strings of dead stems which are abraded flat to windward.

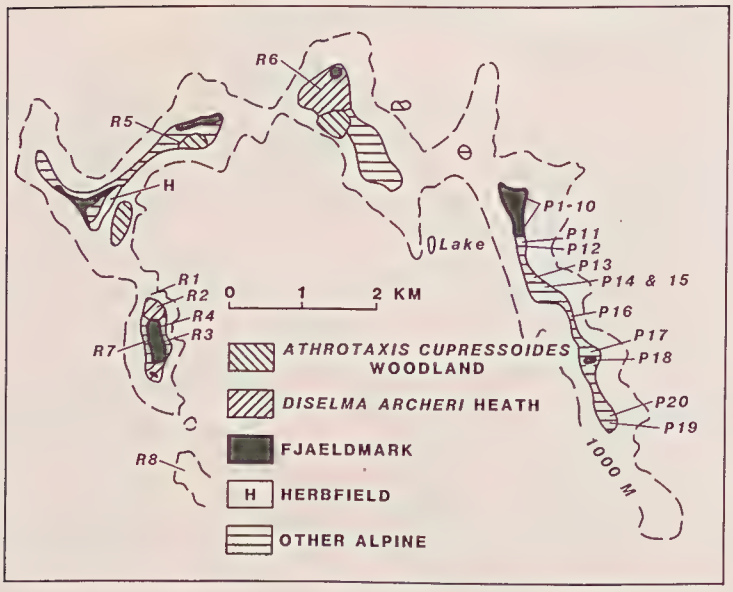

FIG.3 - The distributions of alpine plant communities and *Athrotaxis cupressoides* woodland.

Nonsorted stone steps (Washburn 1979) occur on the slightly steeper slopes surrounding the stone pavements occupied by migrating shrubs (plate 1). They are also found on Rocky Hill and on the southern aspect of the aptly named Pyramid Mountain. At Pyramid Mountain the nonsorted stone steps imperceptibly change to nonsorted stone stripes, the transition occurring at a general slope angle of approximately 8°. The steps and stripes have an alignment independent of the underlying rock stratigraphy. The treads of both steps and stripes support only an extremely sparse cover of *Drapetes tasmanica*, *Senecio pectinatus* and, occasionally, *Dichosciadeum ranunculaceum*. The risers are fully vegetated with herbs such as *Senecio leptocarpus* and *Milliganía densiflora* sheltering under 0.2-0.5 m tall tangled shrubs (plate 2). On the Pyramid Mountain steps and stripes, the risers vary in height from 1.00 to 1.75 m and in width from 1.50 to 3.0 m, while the treads vary in width from 4 to 9 m. On the stone stripes the treads have their maximum steepness parallel to the risers, this slope being typically in the range 15-25°. The material in the treads consists of small shattered rock particles over a mixture of rock particles and fines. Vegetation traps rock and soil particles, creating the steep (25-40°) risers. Particles are moved downhill by water and by gravitational movement after needle ice disruption. Finer particles are transported uphill by the strong prevailing westerly winds until trapped in the riser vegetation.

On hills A and C (fig. 1) flat, bare areas have developed amongst *Diselma archeri* coniferous heath. These areas are occupied by pools of water after heavy or prolonged rain, the alternation between inundation and exposure excluding higher plant growth. Small lunette dunes form to the leeward of these features (plate 3) which show evidence of erosion rather than deposition on their other margins.

Snow Patch Vegetation

A distinct vegetation is found in those situations below the leeward edges of plateaus and peaks where snow tends to accumulate and be protected from wind ablation. Steep, slightly stepped east-facing slopes develop a characteristic vegetation sequence (table 2,

R4 and P20), probably related to snow patch duration, movement and melting patterns. At the break of slope between the plateau and the snow patch there is a dense growth of metre tall shrubs with their foliage extended away from the prevailing winds and pruned to the general height of the nearby plateau. *Leptospermum rupestre* is the dominant species in this zone. On the steep slopes immediately below the *L. rupestre* heath there is a mat heath dominated by *Cyathodes dealbata* and *Pentachondra pumila*. *Microcachrys tetragona* forms a prostrate coniferous heath immediately below the mat heath and in turn gives way to a heath in which *Richea sprengelioides* and *Helichrysum backhousii* are the most prominent species as the slope gets successively gentler and the snow lie more prolonged. *Richea sprengelioides*, *H. backhousii* and *M. tetragona* have a characteristic growth habit in these snow patch situations, their stems extending down hill, and being upright only at their extremes, thus incurring minimum damage with snow movement. *Nothofagus cunninghamii* scrub is found below the snow patch vegetation.

The largest snow patch in the study area occurs along the base of the uppermost cliffs on Rocky Hill. The southernmost part of this patch is a *Milligania densiflora* tall alpine herbfield. The northern part of the patch supports a short alpine herbfield dominated in wet areas by *Ranunculus nanus* and *Juncus antarcticus*. Short alpine herbfield also occurs in patches along stream lines in the *Nothofagus cunninghamii* scrub below the herbfield.

PLATE 1 - Nonsorted stone steps.

PLATE 2 - Stone stripe riser and tread.

PLATE 3 - Lunette dune to east of an intermittent pool.

Short Alpine Herbfield

Short alpine herbfield is most extensive on Rocky Hill, but even there occupies less than one hectare. It is found mostly on convex deposits on fines below cliffs and along stream lines. The convexity of these deposits is due to the effective trapping of silt and clay particles by the uppermost vegetation where water moves in a sheet flow. The alpine herbfields are intensively grazed by marsupials which may be responsible for maintaining them as short swards. There is considerable floristic variation related to drainage status, with *Ranunculus* spp. being most common along the most persistent drainage lines and *Acaena montana*, *Rubus gunnianus* and *Permettya tasmanica* characterizing some of the less constantly soaked situations. Small grasses such as *Agrostis parviflora*, *Erythranthera*

australis and *Danthonia pulvinorum* are intimately mixed with herbs such as *Microseris scapigera, Plantago paradoxa, Epilobium gunnianum, Hypericum japonicum* and *Colobanthus apetalus*. Many of the species recorded for the short alpine herbfields were confined to this vegetation type in the study area (table 1).

A small area of short alpine herbfield was located on the peak of Pyramid Mountain. This contained two species, *Helichrysum acuminatum* and *Drapetes tasmanica* that were absent from the Rocky Hill herbfield, and lacked many of the species found at Rocky Hill, but resembled this latter herbfield in its structure and local species richness. Small areas of the less species-rich *Gunnera cordifolia* short alpine herbfield were found between *Astelia alpina* tall alpine herbfield and *Athrotaxis cupressoides* woodland at Rocky Hill.

Other Alpine Vegetation Types

Of the alpine vegetation types recognized by Kirkpatrick (1983) only tussock grassland and deciduous heath are absent from the study area, and, excluding the communities described above, bolster heath, coniferous heath, heath, tall alpine herbfield and bog communities can all be found.

Bolster heath dominated by *Donatia novae-zelandiae* is absent from the Pyramid Mountain alpine area but is found on all others within the study area. The bolster plants *Abrotanella forsteroides, Dracophyllum minimum, Phyllachne colensoi, Pterygopappus lawrencii* and *Mitrasacme archeri* were not observed within the study area, although *Carpha rodwayi, Oreobolus pumilio, O. oligocephalus* and *Ewartia meredithae* were present. On the relatively low altitude quartzite, hill D, *Donatia novae-zelandiae* shares dominance with *Gymnoschoenus sphaerocephalus*. Elsewhere the most abundant associates include *Microcachrys tetragona, Empodisma minus* and *Oreobolus oligocephalus*.

On hills A and C *Donatia* bolster heath is replaced on slightly better drained ground by *Diselma archeri* coniferous heath. The *D. archeri* bushes are up to 1.8 m tall and vary from sparse to dense cover. *Microcachrys tetragona* coniferous heath occurs on all hills and mountains within the study area, being mostly located on shallow soils with gentle slopes. Other alpine heath dominants recorded for the study area are *Epacris serpyllifolia, Baeckea gunniana, Cyathodes dealbata, Pentachondra pumila, Leptospermum rupestre, Richea scoparia* and *Nothofagus cunninghamii*. The latter species forms a metre high heath, with approximately 50% cover in the dominant stratum, in a belt between *N. cunninghamii* scrub and the higher altitude heath communities.

On the shelves below the upper treeline some poorly drained areas are occupied by bog in which *Sphagnum cristatum* is ubiquitous and *Richea gunnii, Astelia alpina* and *Carex gaudichaudiana* are prominent, or by *Astelia alpina* tall alpine herbfield.

Other Vegetation

The numerous cliffs found in the study area support a sparse vegetation characterized by faithful species such as *Gnaphalium umbricola* and *Aristotelia peduncularis*. The cliffs are rich in ferns, grasses and soft herbs such as *Veronica calycina* and *Geranium sessiliflorum* (table 1).

The subalpine heaths are dominated by *Melaleuca squamea*, which is typically more than 1 m tall. On the most poorly-drained sites these heaths grade into *Gymnoschoenus sphaerocephalus* tussock sedgeland. With slightly improved drainage they grade into *Leptospermum nitidum* scrub and forest which, with improved drainage, in turn gives way to *Eucalyptus simmondsii* open-forest or *Eucalyptus subcrenulata* woodland over *Nothofagus cunninghamii* closed-forest.

Eucalyptus coccifera open-scrub, open-forest and woodland forms a narrow altitudinal belt terminating at the upper slope treeline on the western and northern aspects of both mountains where slopes are steep. On the other aspects *Nothofagus cunninghamii* scrub predominates below the treeline. *Athrotaxis cupressoides* woodland is confined to two shelves and two, high altitude, south-facing half-basins (plate 4). A few individuals of

A. selaginoides were found in the central *A. cupressoides* woodland (fig. 3), and only one individual was found in the Pyramid Mountain alpine area.

The one lake in the study area (fig. 3) contained a small area of reed swamp dominated by an unidentified sedge or rush, and in various parts its aquatic vegetation was dominated by *Potamogeton australiensis*, *Isoetes gunnii* and *Myriophyllum pedunculatum*. A low closed-herbland dominated by *Scirpus subtilissimus* and *Myriophyllum pedunculatum* is found at the northern end of the lake where also is found a *Richea gunnii-Sphagnum cristatum* bog. A *Leptospermum lanigerum* closed-forest occurs on slightly better-drained ground than the bog. A soft organic deposit more than 2 m deep underlies the bog and the aquatic vegetation near the north and west shores of the lake.

PLATE 4 - *Athrotaxis cupressoides* woodland mixed with bog on a shelf below Rocky Hill. The boundary of the last fire is marked by tree skeletons. *Nothofagus cunninghamii* scrub occupies the foreground.

DISCUSSION

The study area contains evidence for at least two major fires, and for a recent period of severe landscape instability. Very little vegetation could have escaped a fire which eliminated *Athrotaxis* spp. and *Diselma archeri* from most of the sites suitable for their occurrence. On the southern flanks of the fjaeldmark of hill A a metre-deep gully has been cut through a nonsorted stone step revealing a large *Athrotaxis* log at an altitude presently bereft of tree growth. Many such buried logs were also revealed by erosion, or found partly protruding from the soil, on the upper terraces of Rocky Hill. The event that killed these trees must have affected almost all of Pyramid Mountain where only one individual of *Athrotaxis* and no *Diselma* were found.

A second fire burned most of Rocky Hill, probably in 1934. This fire further reduced the area occupied by *Athrotaxis cupressoides* but missed the small remaining areas of *Diselma archeri* heath, and could not burn the fjaeldmark. An earlier fire almost certainly occurred within the last one or two centuries as many individuals of *Nothofagus cunninghamii* and *Eucalyptus subcrenulata*, while large enough to be one or two centuries old, show evidence of being derived from resprouts from the base of older stems. The buried *Athrotaxis* logs were probably killed by fire as they occur on gentle enough slopes to exclude landslip or avalanche and windthrow does not seem to be common with these species. The *Athrotaxis* skeletons remain standing for several decades following fire kill, so their burial must be related to a later event. The presence of *Athrotaxis* logs beneath fjaeldmark cannot be taken as evidence of a warmer climate in the recent past as *Athrotaxis* survives as a tree at higher altitude on the nearby northeastern spur of Rocky Hill. However, this situation does suggest that an extremely long period without fire preceded the event that killed the now-buried *Athrotaxis*, as trees as large as that found buried have been shown to be 300 years old in a less exposed environment (Kirkpatrick & Harwood 1980), and as the occupation of a potential fjaeldmark site by forest would require a long term building up of vegetation shelter to windward.

Nonsorted stone steps and nonsorted stone stripes are associated with the sandstones and mudstones of the Tasmanian high mountains. Outside the study area either or both of these features also occur on Dome Hill, Castle Mountain, High Dome, Last Hill, Camp Hill, Little Sugarloaf, Goulds Sugarloaf, Mt Rufus, the Boomerang and the Southern Range (fig. 1). The migrating fjaeldmark type is also known from the Boomerang and Mt La Perouse in the Southern Ranges. The proportion of Tasmanian fjaeldmark that could be occupied by other vegetation types in the extremely long term absence of fire is uncertain. In the cases of extremely steep-sided and unstable ridges and poorly drained horizontal pavements even minor disturbance might be sufficient to lead to an accelerating break in plant cover.

Where shrubs and trees could establish complete cover on steep screes they would tend to accumulate sediment from above, and thus become prone to landslip, a common feature of steep subalpine slopes in Tasmania even where fire has been long absent.

One notable feature of the alpine vegetation of the area burned in the earlier fire is the ubiquity of *Microcachrys tetragona*, a species among those most susceptible to fire. This ubiquity suggests a means of medium distance dispersal, a means provided by the mountain jay (*Strepera fuliginosa*) whose cigar-shaped regurgitate contained virtually unmodified sections of the *Microcachrys* cones in a matrix of *Pentachondra pumila* fruits in January 1983 throughout the study area.

The partly random nature of survival after fire, and dispersal from surviving individuals, may account for much of the variation observed within and between the vegetation of Tasmanian high mountains, as must the patterning of the dispersal paths available during the Last Glacial. However, despite some noticeable idiosyncracies, the vegetation and flora of Rocky Hill and Pyramid Mountain fit well within the available statewide models, which are based on present environmental conditions.

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TABLE 1

TAXA OBSERVED ON ROCKY HILL AND PYRAMID MOUNTAIN

	Alpine		Subalpine				
	Pyramid Mtn	Rocky Hill	Forest	Cliff	Herb-field	Heath/scrub	Aquatic
PTERIDOPHYTA							
ASPIDIACEAE							
Polystichum proliferum	x	x	x	x			
ASPLENIACEAE							
Asplenium trichomanes				x			
ATHYRIACEAE							
Cystopteris fragilis (L.) Bernb.				x			
BLECHNACEAE							
Blechnum fluviatile				x			
B. penna-marina	x	x		x	x		
B. vulcanicum (Bl.) Kuhn				x			
B. wattsii Tindale			x				
GLEICHENIACEAE							
Gleichenia alpina	x	x					
GRAMMITIDACEAE							
Grammitis billardieri			x				
HYMENOPHYLLACEAE							
Hymenophyllum peltatum			x				
ISOETACEAE							
Isoetes gunnii							x
LYCOPODIACEAE							
Huperzia selago		x					
Lycopodium fastigiatum	x	x		x	x		
L. scariosum	x	x					
GYMNOSPERMAE							
CUPRESSACEAE							
Diselma archeri		x	x				
PODOCARPACEAE							
Microcachrys tetragona	x	x					
Phyllocladus asplenifolius	x	x	x				
Podocarpus lawrencii	x	x					
TAXODIACEAE							
Athrotaxis cupressoides		x	x				
A. selaginoides	x	x					
ANGIOSPERMAE							
MONOCOTYLEDONEAE							
CENTROLEPIDACEAE							
Centrolepis monogyna	x	x					
C. muscoides	x	x					

Rocky Hill and Pyramid Mountain Vegetation

	Alpine		Subalpine				
	Pyramid Mtn	Rocky Hill	Forest	Cliff	Herb-field	Heath/ scrub	Aquatic
CYPERACEAE							
Carex appressa			x	-	-	x	-
C. gaudichaudiana		x					
Carpha alpina	x	x	x			x	
C. curvata W.M. Curtis ined.		x					
C. rodwayi W.M. Curtis ined.	x	x					
Gahnia grandis							
Gymnoschoenus sphaerocephalus			x			x	
Lepidosperma filiforme		x				x	
L. lineare var. *inops*	x	x					
Oreobolus acutifolius	x	x					
O. oligocephalus W.M. Curtis ined.	x	x					
O. pumilo	x	x					
Schoenus calyptratus	x	x					
Scirpus aucklandicus		x	x	-	x	x	
S. fluitans							x
S. subtilissimus						x	
S. sp.							x
Uncinia compacta R.Br.	x	x					
U. flaccida	x			x			
U. tenella			x				
HYPOXIDACEAE							
Campynema lineare	x	x					
IRIDACEAE							
Diplarrhena latifolia	x	x	x	-	-	x	-
Isophysis tasmanica		x					
JUNCACEAE							
Juncus antarcticus	x	x	-	-	x	-	-
J. sp. 1			x				
J. sp. 2				x			
Luzula spp.	x	x	-	x	x	-	-
LILIACEAE							
Astelia alpina	x	x	x			x	
Blandfordia punicea	x	x	x			x	
Libertia pulchella				x			
Milligania densiflora	x	x		x			
ORCHIDACEAE							
Prasophyllum alpinum	x	x					
Pterostylis dubia	x	x		x			
Thelymitra sp.		x					
POACEAE							
Agrostis aemula				x			
A. parviflora					x		
A. venusta	x	x		x	x		
Danthonia fortunae-hibernae			x	x		x	
D. nivicola	x	x					
D. pauciflora	x	x			x		
D. pulvinorum D.I. Morris					x		
Deyeuxia carinata	x	x		x			
D. monticola	x	x		x		x	
D. sp.	x	x		x			

	Alpine		Subalpine				
	Pyramid Mtn	Rocky Hill	Forest	Cliff	Herb-field	Heath/ scrub	Aquatic
Erythranthera australia (Petrie) Zotov					x		
Hierochloe fraseri	x	x					
H. redolens						x	
Microlaena tasmanica	x	x	x	x		x	
Poa gunnii	x	x			x	x	
P. labillardieri Steud.	x						
P. saxicola	x						
POTAMOGETONACEAE							
Potamogeton australiensis							x
RESTIONACEAE							
Calorophus elongatus						x	
Empodisma minus (Hook. F.) Johnson & Cutler	x	x	x			x	
Restio complanatus		x				x	
XYRIDACEAE							
Xyris marginata		x				x	
DICOTYLEDONAE							
APIACEAE							
Actinotus bellidioides						x	
A. moorei		x					
A. suffocata	x	x					
Dichosciaduem ranunculaceum	x						
Diplaspis hydrocotyle					x		
Hydrocotyle sibthorpioides	x	x			x		
Oreomyrrhis ciliata	x	x			x		
ASTERACEAE							
Abrotanella scapigera		x	-	x	-	-	-
Brachycome tenuiscapa		x			x		
Celmisia longifolia	x	x					
Cotula alpina		x			x		
Erigeron pappachroma	x	x	x				
E. stellatus	x	x					
Ewartia meredithae	x	x					
E. planchonii	x	x		x	x		
Gnaphalium traversii	x	x			x		
C. umbricola				x			
Helichrysum acuminatum	x						
H. backhousii	x	x					
H. ledifolium		x					
H. milliganii	x	x					
H. pumilum		x					
H. scorpioides			-	x	-	-	-
Lagenifera stipitata		x	x		x		
Microseris scapigera					x		
Olearia ledifolia	x	x			x		
O. persoonioides			x				
O. phlogopappa				x			
O. pinifolia	x	x	x				
Senecio gunnii				x			
S. leptocarpus	x	x					
S. pectinatus	x	x					

Rocky Hill and Pyramid Mountain Vegetation

	Alpine		Subalpine				
	Pyramid Mtn	Rocky Hill	Forest	Cliff	Herb-field	Heath/ scrub	Aquatic
BORAGINACEAE							
Mysotis australis			x	x			
BRASSICACEAE							
Cardamine sp.					x		
CAMPANULACEAE							
Wahlenbergia saxicola	x	x		x	x		
CARYOPHYLLACEAE							
Colobanthus apetalus					x		
CUNONIACEAE							
Anodopetalum biglandulosum			x				
Bauera rubioides	x	x	x	-	-	x	
DILLENIACEAE							
Hibbertia procumbens						x	
DONATIACEAE							
Donatia novae-zelandiae		x					
DROSERACEAE							
Drosera arcturi	x	x	-	-	x	-	-
D. pygmaea					x		
ELAEOCARPACEAE							
Aristotelia peduncularis			-	x	-	-	-
EPACRIDACEAE							
Archeria eriocarpa			x				
A. hirtella			x				
A. serpyllifolia	-	x					
Cyathodes dealbata	x	x					
C. parvifolia	x	x	x				
C. petiolaris	x	x					
C. straminea	x	x	x				
Epacris serpyllifolia	x	x				x	
Lissanthe montana	x	x	x	x			
Monotoca sp. aff. *linifolia*	x	x					
M. submutica			-	-	-	x	-
Pentachondra pumila	x	x	-	-	-	x	-
Prionotes cerinthoides		x	x	x			
Richea gunnii	x	x					
R. pandanifolia	x	x	x				
R. scoparia	x	x	x			x	
R. sprengelioides	x	x	x				
Sprengelia incarnata	x	x	x			x	
Trochocarpa cunninghamii	x	x	x				
T. gunnii			x				
ERICACEAE							
Galtheria hispida	x	x	x	x	-	-	-
Pernettya tasmanica	x	x					

	Alpine		Subalpine				
	Pyramid Mtn	Rocky Hill	Forest	Cliff	Herb-field	Heath/ scrub	Aquatic
ESCALLONIACEAE							
Anopterus glandulosus			x				
Tetracarpaea tasmanica	x	x	x				
EUCRYPHIACEAE							
Eucryphia lucida			x				
E. milliganii			x	-	-	x	-
FABACEAE							
Oxylobium ellipticum		x	x			x	
FAGACEAE							
Nothofagus cunninghamii	x	x	x			x	
GENTIANACEAE							
Gentianella diemensis	x	x					
GERANIACEAE							
Geranium potentilloides			x	x	-	-	-
G. sessiliflorum				x	x		
HALORAGACEAE							
Gonocarpus micranthus Thunb.		x			x		
G. montanus (Hook. f.) Orchard	x	x	x				
Gunnera cordifolia		x					
Myriophyllum pedunculatum							x
HYPERICACEAE							
Hypericum japonicum	x	x	-	-	x		
LOGANIACEAE							
Mitrasacme montana	x	x				x	
MYRTACEAE							
Baeckea gunniana	x	x				x	
Eucalyptus coccifera			x			x	
E. simmondsii Maiden			x			x	
E. subcrenulata			x			x	
E. vernicosa		x					
Leptospermum lanigerum			x			x	
L. nitidum			x			x	
L. rupestre	x	x					
Melaleuca squamea						x	
ONAGRACEAE							
Epilobium gunnianum			-	-	x		
E. tasmanicum			x	x	-		
OXALIDACEAE							
Oxalis lactea	x	x	x	x	x	-	-
PLANTAGINACEAE							
Plantago daltonii			x		x		
P. paradoxa					x		
P. tasmanica	x	x					

Rocky Hill and Pyramid Mountain Vegetation

	Alpine		Subalpine				
	Pyramid Mtn	Rocky Hill	Forest	Cliff	Herb-field	Heath/ scrub	Aquatic
PROTEACEAE							
Agastachys odorata			x	-	-	x	
Bellendena montana	x	x					
Lomatia polymorpha			x				
Orites acicularis	x	x					
O. diversifolia						x	
O. milliganii			x				
O. revoluta	x	x	x			x	
Persoonia gunnii	x	x	x			x	
Persoonia sp.			x			x	
Telopea truncata			x			x	
RANUNCULACEAE							
Anemone crassifolia		x				x	
Ranunculus collinus							x
R. decurvus			-	-	x	-	-
R. glabrifolius					x		
R. nanus					x		
R. triplodontus					x		
ROSACEAE							
Acaena montana		x			x		
A. novae-zelandiae			x			x	
Rubus gunnianus	x	x	x		x	x	
RUBIACEAE							
Coprosma moorei	x						
C. nitida	x	x	x	-	-	x	
C. pumila	x	x					
Galium ciliare			-	x	-	-	
RUTACEAE							
Boronia citriodora						x	
SANTALACEAE							
Exocarpos humifusus	x	x					
Leptomeria glomerata		x				x	
SCROPHULARIACEAE							
Euphrasia gibbsiae		x					
E. striata	x	x					
Ourisia integrifolia			-	x	-	-	-
Veronica calycina				x			
STYLIDIACEAE							
Stylidium graminifolium	x	x				x	
THYMELACEAE							
Drapetes tasmanica	x						
Pimelea lindleyana						x	
TREMANDRACEAE							
Tetratheca procumbens	x						
VIOLACEAE							
Viola hederacea	x	x	-	-	x	-	-
WINTERACEAE							
Drimys lanceolata	x	x	x			x	

TABLE 2

SPECIES ASSOCIATION IN THE ALPINE VEGETATION

	P2	P6	P7	P3	P5	P8	P1	P9	P10	P4	P18	R7	R4	P20	P12	R3	P11	P14	P15	P16	P17	R8	R1	R2	R5	P21	R6	P13	P19
Coprosma nitida	-	x	x	-	-	-	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deyeuxia monticola	x	x	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dichosciadeum ranunculaceum	x	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantago tasmanica	-	x	x	x	x	x	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Drapetes tasmanica	x	-	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agrostis venusta	x	-	x	-	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Senecio leptocarpus	x	x	-	x	x	-	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Richea sprengelioides	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	x	-	-	-	-	-	x	-	-	x
Senecio pectinatus	x	x	x	x	x	x	x	x	x	x	x	x	-	-	x	x	-	-	-	-	-	-	x	-	-	-	-	-	-
Exocarpos humifusus	x	x	x	x	x	-	x	x	x	x	x	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Helichrysum backhousii	x	x	-	x	x	x	x	x	x	x	x	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bellendena montana	x	x	-	x	x	-	x	-	x	x	x	-	x	x	x	-	x	-	x	-	x	-	-	x	-	-	-	-	-
Orites revoluta	x	x	x	x	x	-	x	x	x	x	x	x	-	x	-	x	x	-	-	-	x	-	-	x	x	x	-	-	x
Olearia ledifolia	x	x	x	x	x	-	-	x	x	-	-	-	-	-	-	x	-	-	-	-	-	-	-	x	x	-	-	-	-
Epacris serpyllifolia	x	x	-	x	x	x	x	x	x	x	-	x	-	x	x	x	x	x	x	x	x	-	x	x	x	x	x	x	x
Poa gunnii	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-	-	x	-	-	-	x	-	-	x	x
Euphrasia striata	x	x	x	x	x	x	x	x	x	x	-	x	x	x	-	x	x	-	x	-	-	-	-	x	-	x	x	x	-
Pentachondra pumila	x	-	x	x	x	-	-	x	x	-	x	x	x	x	x	x	x	-	-	x	x	-	x	x	x	-	x	-	x
Helichrysum milliganii	-	-	x	x	-	-	-	-	x	x	x	x	x	-	x	x	x	x	-	x	x	-	-	-	-	x	x	-	-
Leptospermum rupestre	-	-	-	-	-	-	x	-	-	x	-	x	x	x	x	x	x	-	-	-	-	-	-	-	x	x	-	-	x
Gonocarpus montanus	-	-	-	x	-	-	-	x	x	-	x	-	x	x	x	-	-	-	-	-	-	-	-	-	x	-	-	-	x
Lycopodium fastigiatum	-	-	-	x	-	-	x	-	-	-	x	-	-	-	x	-	x	-	-	-	-	-	-	-	-	x	-	-	-
Campynema lineare	-	-	x	-	-	-	-	-	-	x	x	x	x	-	-	x	x	-	-	-	-	-	x	-	-	x	-	-	-
Gentianella diemensis	x	-	-	x	-	-	x	-	-	-	-	-	-	-	x	x	x	-	x	x	-	-	x	x	x	-	x	x	-
Astelia alpina	-	-	-	-	-	-	x	-	x	-	-	-	x	-	-	x	-	-	x	x	-	-	-	x	x	x	x	x	x
Empodisma minus	-	-	-	-	-	-	-	x	x	x	x	-	-	-	x	x	x	x	x	x	-	x	x	x	-	x	x	x	x
Microcachrys tetragona	-	-	-	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x	x	x	-	x	x	x	x	x	x	x
Cyathodes dealbata	-	-	-	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x	x	x	x	-	x	x	x	x	x	x
Erigeron stellatus	-	-	-	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	-	-	x	x	x	x	x	x	x	x	-
Carpha alpina	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	-	x	x	x	x	x	x	x	x	x	x	x	x	x
Mitrasacme montana	-	-	-	-	-	-	-	-	-	-	x	-	-	-	x	-	-	-	-	-	x	-	x	-	x	x	-	-	-
Oreobolus oligocephalus	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	x	-	-	-	-	-	-	x	x	-	-	x	-	-
Oreobolus acutifolius	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	x	-	-	x	x	-	-	-	x	-	-	-	-

TABLE 2 cont.

SPECIES ASSOCIATION IN THE ALPINE VEGETATION

	P2	P6	P7	P3	P5	P8	P1	P9	P10	P4	P18	R7	R4	P20	P12	R3	P11	P14	P15	P16	P17	R8	R1	R2	R5	P21	R6	P13	P19
Ewartia meredithae	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	x	x	x	x	x	x	x	x	x	x	-	x	-	-
Sprengelia incarnata	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	-	x	x	x	x	x	x	x	x	-	-	-	-
Baeckea gunniana	-	-	-	-	-	-	-	-	-	-	x	-	-	-	x	x	x	-	x	-	x	x	-	x	-	x	-	x	-
Oreobolus pumilio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x	x	x	x	x	x	x	-	x	x	-	-	-
Danthonia pauciflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	x	-	-	x	-	x	x	-	-	-	-	-
Drosera arcturi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	x	x	x	x	-	x	-	-
Gleichenia alpina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x	x	x	-	-	-	-	-	-
Microlaena tasmanica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	-	x	-	-	-	-	-
Actinotus suffocata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	x	-	-	-	x	-	-
Donatia novae-zelandiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	-	-	x	-	-
Anemone crassifolia	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x	x	x	-	-	-	-
Lycopodium scariosum	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	x
Lepidosperma lineare	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-
Uncinia compacta	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	-	-	-	-
Drimys lanceolata	-	-	-	x	x	-	x	-	-	-	-	-	x	-	-	-	x	-	-	-	-	-	-	-	x	-	-	-	-
Diplarrhena latifolia	-	-	-	x	-	-	-	-	-	-	x	-	-	-	-	-	x	x	-	-	-	x	-	-	-	-	-	x	-
Monotoca aff. *linifolia*	-	-	-	-	-	-	x	-	-	-	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Richea scoparia	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	-
Celmisia longifolia	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-

ADDITIONAL SPECIES: *Actinotus moorei* R2, R5; *Archeria serpyllifolia* R5; *Athrotaxis selaginoides* R5; *Blechnum penna-marina* P8; *Carpha rodwayi* R1, R2; *Celmisia longifolia* P1, R3; *Coprosma moorei* P16, P17; *Cyathodes petiolaris* P16, R7; *Diselma archeri* R2, R6; *Erigeron pappachroma* P9; *Euphrasia gibbsiae* R1; *Gaultheria hispida* R4; *Gnaphalium traversii* P8; *Gymnoschoenus sphaerocephalus* R8; *Helichrysum acuminatum* P8, P9; *Helichrysum scorpioides* P8; *Hierochloe fraseri* P10, P13; *Hydrocotyle sibthorpioides* P8; *Leptomeria glomerata* R1; *Lissanthe montana* P8; *Luzula* spp. P1, P2; *Milligania densiflora* P5; *Nothofagus cunninghamii* P19, P20; *Olearia pinifolia* P5, P6; *Oreomyrrhis ciliata* P8; *Orites acicularis* P1, P11; *Pernettya tasmanica* P7, P8; *Phyllocladus asplenifolius* P20; *Restio complanatus* R8; *Rubus gunnianus* P8; *Schoenus calyptratus* R3; *Stylidium graminifolium* P17, R8; *Viola hederacea* P8.

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ABOUT TIME — DAYLIGHT SAVING IN TASMANIA

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ABSTRACT

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Tasmania pioneered Australia's post-World War Two usage of daylight saving by unilaterally adopting it in the summer of 1967 for a six-month period as an emergency energy saving measure. One irony of this move is that it was in 1967 that the atomic clock was adopted as the world-wide device for the measuring of the fundamental unit of time, the second. Thus Tasmania's use of daylight saving moved it ahead of the rest of Australia, but at the same time it was a step backwards into the solar-mechanical time-keeping era.

Nevertheless, Tasmania has a special connection with the use of daylight. The central focus of this paper examines the history of that connection and places it in an international (as well as a national perspective) by presenting some of the more prominent elements of the wider history of daylight saving generally.

GENERAL BACKGROUND

As is said of God, if time did not exist, it would be necessary to invent it. But then time was invented by people in the first place. For time is a facet of human consciousness, albeit one that we experience both in a physical and a psychological manner. Time is also a facet of the observed environment, in that, we note the alteration of day and night and adjust our lives accordingly. Daylight saving is a perfect example of this adjustment; shift work is another.

The four seasons are also manifestations of time. But for the purposes of this paper it is interesting to recall that it was the Egyptian astronomers who first calculated the solar year at close to 365 days. They, however, could not persuade their rulers of the necessity to account for one extra day in every fourth year. So for nearly two hundred years the Egyptian calendar grew increasingly out of phase with the seasons.[1] [1 - see endnotes].

It was not until 46 BC that Julius Caesar issued a decree instituting the concept that we know today as the 'leap year'. But even under the new Julian Calendar the interaction of time and the seasons, and especially man's adjustment to them, was quite inaccurate. Maladjustment was the case until the 16th Century when the error was so great that, in 1582, Pope Gregory XIII, following furious debate, radically altered the calendar system to approximate that which we use today. Most interestingly, to correct the seasonal disparities of the old calendar Pope Gregory decreed that for the year 1582, October 4th would be followed by October 15th, thus removing ten days from people's lives. Whilst this had no drastic consequences (except for those that lost their birthdays!) many Protestant countries in Europe refused to follow suit for hundreds of years. England, for example, waited so long that in 1752 when they did change, eleven days had to be lost, and the 2nd September was to be followed by the 14th. A final example of this switching process occurred in Russia in 1918 when Lenin decreed that the 1st February would in fact be the 14th instead. The new government also instituted a period of two-hour daylight saving to help improve the economy following the revolutionary disruptions.

Nevertheless, the Gregorian Calendar was substantially agreed upon. Then, it is claimed, the famous American Benjamin Franklin first thought of the idea of daylight saving

in 1776 during the War of Independence. He did not however document his thoughts until he wrote of them in a whimsical essay in 1784, showing, for example, that daylight saving would conserve tallow, which was then a common means of creating artificial light.

But it was not until the 20th Century that daylight saving was to be seriously advocated, this time in England. Before detailing some of this story it seems appropriate to briefly mention the great deal of effort necessary to effect some standardization of time-keeping.

In England, although it was nearly universally used for navigation, Greenwich Mean Time was not adopted as a common time standard until 1880. Then in 1884 delegates from some 27 nations met in Washington D.C. and agreed to a detailed plan for the standardization of global time. The scheme agreed to was to use an International Dateline, and to institute a time-zone pattern, both of which we still use today. Moreover, at the same time the railmen of the U.S.A. were also successful in gaining for themselves a four-zone time system for the whole of the American continent. This was not, however, officially sanctioned by law until March, 1918.

RISE OF DAYLIGHT SAVING IN THE U.K.

Between 1905 and 1907 William Willet, of the Royal Astrological Society in London, promoted daylight saving for England. He even wrote a pamphlet entitled, "Waste of Daylight", in which he claimed that each person in the U.K. wasted 154 hours of daylight per year. This was calculated because it assumed that most people remained in bed until a given time registered upon their bedside clock, i.e. rarely did they actually lose sleep, merely 'staying-in-bed time'. His idea was to advance the clocks by 80 minutes, in four moves of 20 minutes each during late spring and into summer.

Willet's persistent advocacy gained many converts, perhaps the most famous of whom was the then Home Secretary, Winston Churchill. But it was not until 1908-1909 that a certain Mr Dobson introduced a bill into the House of Commons to adjust the clocks by one hour. Further bills were introduced in 1911, 1912, 1913 and 1914, each of which were the subject of Select Committee investigation.

One segment of the report from one of these investigations captures the essence of its favourable recommendation:

> "The apex to which the whole movement converges is leisure after the routine of the day while the sun is still shining, and it is the way in which such leisure may be used by various individuals, that causes the seasonable change proposed by the Daylight Saving Bill to make such an extraordinary appeal to the metropolitan mind."[2]

However, each and every bill proposed was rejected outright by the British Parliament.

There was also a bill introduced in July 1909 into the Victorian Parliament. This also followed the Willet plan for an 80 minute advance of the clocks, in four 20 minute steps. The Select Committee established to consider the bill concluded that:

> "The strongest feature of the principle is, with the clocks once changed, at a time when people would not realize it, life would go on as before."[2]

Nevertheless, the Committee recommended that only a single hour be altered, and in one step. The bill failed regardless of the favourable report.

The British did introduce daylight saving during the First World War, basically as a response to its use by their enemy, the Germans. Allies such as the Americans and the Australians also introduced some daylight saving, as will be shown below. Naturally, this war-time use of daylight saving was seen as an emergency fuel-saving measure, and thus the members of the House of Commons switched markedly and voted overwhelmingly in its favour, by some 170-2 votes, in fact. Daylight saving was reintroduced and made permanent in 1925 by the Summer Time Act and remained so in the U.K. until 1947. For during the Second World War the British adopted double daylight saving by turning their clocks forward by two hours until 1947 when they reverted to the single hour. This was confirmed by a new Standard Time Act passed in 1968.

To close this international segment of the paper it is worth noting that of the many nations using daylight saving it is significant that the U.S.A. has a fixed system. An initial investigation was made in 1919 for a national scheme, but it was not until April 1967 that the Federal government, upon the advice of several Senate Commerce Committee reports (1963-1965) directed that a common period be used throughout America. This was a way to avoid the chaos of the local variations, both between and within parts of the States. The U.S. House of Representatives vote in favour of the national scheme was overwhelming, some 292-93 votes. Moreover, the Uniform Time Act created the eight time zones that replaced the older four zones "established" in the 1880's by the railway men. Finally, to conserve energy President Nixon signed a Bill on 15th December 1973 to put the whole of the U.S.A. onto year-round daylight saving for two years (from 6.1.1974 to 26.10.1976); this plan, however, lapsed and the regular scheme returned.

AUSTRALIAN BACKGROUND

Australia has a connection with time that is often overlooked.[3] Lt Cook, as he then was, was instructed to travel to Tahiti to observe the transit of Venus due to take place on 3rd June 1769. He was then to sail on in search of "Terra Australis", the Great South Land. His observations of Venus were designed to assist in the calculation of the distance of the Sun from the Earth (i.e. time and distance based upon the speed of light) and thereby greatly improve astronomical and navigational science.

Cook's first voyage was significantly helped by improved navigational data prepared from earlier lunar calculations. He was thus far better equipped to plot his position accurately - hence the excellence of his cartography. Because of accurate plotting Cook, the British Navy's best navigator, was able to prove that no Great South Land existed, instead he discovered New South Wales, on 20th April 1770.

Time had another connection with Cook. On his second Pacific voyage he was able to plot his position even more accurately, as he had several of the new chronometers on board. In 1714 John Harrison had won a £20 000 prize for developing a clock that would maintain its accuracy on an ocean-going vessel, a clock that would withstand the extremes of temperature and movement as it crossed the Equator and faced howling gales. Cook was able to use a "copy" of Harrison's clock made by Larcum Kendall as his means of plotting the longitudinal position of his vessel, the reckoning of which required the accurate computation of the local time and its comparison with Greenwich Mean Time, using the navigational almanac of lunar calculations to assist. Thus accurate determination of time based on a precise solar observation became inseparable from successful navigation.

AUSTRALIAN STANDARD TIME

The several Australian colonies, as they still were until 1901, based their own time-keeping, especially for their capital cities, on the mean solar day for their area. This, of course, led to many variations, both between the within each colony. Indeed even Hobart and Launceston had different times, and they are practically along the same longitide and only some 200 km apart.

This confusion caused increasing difficulties in Australia, as it did world-wide, following the vast improvements in communication between distant places. For example, the coming of the Overland Telegraph system in Australia in 1872 instantaneously linked Australian capital cities and international locations, yet they still had uncoordinated local times.

Thus at an inter-colonial conference of surveyors held in Melbourne in November 1892, a proposal was agreed to that established an Australian standard time using a three-zone pattern based upon the meridian division, so as to account for the variations in the continental sunrise. The new Australian standard, of course, was also to be based upon a calculation from G.M.T.

Following the support for this proposal from inter-colonial postal conferences during 1894-1895 each State legislature set about enacting legislation to give effect to this

scheme. The Standard Time Acts were passed by each Parliament quite easily. But in typical Australian fashion the introductory dates for the scheme differed across the nation:

Queensland	1st January 1895
New South Wales)	
South Australia)	1st February 1895
Victoria)	
Tasmania	1st September 1895
Western Australia	1st December 1895

As a further complication South Australia amended its Standard Time Act in 1898, so that on 1st May 1899, it moved its clocks forward by one half hour. In future it would be 9½ hours rather than 9 hours ahead of G.M.T. Except for daylight saving there has been no other alteration to the Australian standard time scheme.

TASMANIAN BACKGROUND

During Hobart's early development time setting was a regular problem, especially without a standard time for accuracy, and the Government was forced to purchase a series of public clocks. In 1851 six new clocks were obtained at £600 each to help the citizens set their pocket watches and mantel clocks.[4] The new clocks were to be placed in church towers around the city and the State.

The differences in time between the various States before 1895 have already been mentioned. It is perhaps appropriate here to touch upon one small element of setting standard time for Hobart. On 21st February 1894, Lt Commander H.E. Purey-Cust (*H.M.S. Dart*) received a written request, via the Rear Admiral, from the Tasmanian Premier, Mr Braddon, dated 20th February, asking him to investigate the difficulty in ascertaining the correct time for the city.

In his report to Parliament,[5] Purey-Cust mentioned that the main difficulties centred upon the "transit" instruments and the observations taken from the Mt Nelson signal station. The Hobart-based equipment often suffered bad vibration from the trams that passed either side of the observatory, not to mention the variations in temperature that the clocks underwent in an over-exposed location. Despite the availability of an electric signalling device the regular method of time setting was manual because of the frequent failure of the other equipment.

Since 1874, it was from sightings from Mulgrave Battery (now Battery Point), Hobart, that the daily firings of the one o'clock cannon was determined, and shipping advised of the correct time. Purey-Cust noted in his report that:

> "... the present means of communicating it [time] to the shipping in port by means of the time bell are quite inadequate and liable to error."

Public time was regulated by the signal station personnel, one of whom dropped a cannon ball from the top of a pole, and when it "appeared" to hit the ground the gun was fired in Hobart. On this Purey-Cust had this to say:

> "He actually lets go about 1 second to 1 p.m. and the ball itself drops about half a second past 1 o'clock ... under the circumstances it is absolutely impossible for the man to drop the ball exactly at 1 p.m."

There was little that he could recommend apart from the purchase of better time-keeping equipment and the improved location of it in basement rooms away from the summer sun and winter chill. This interaction between the Navy and the citizenry at least shows a continuation of the Captain Cook tradition.

Very little appears to have taken place subsequently for many decades in the history of time-keeping in the State. A witness to the 1915 committee mentioned below, a William Percival Brownell, an ex-politician, said that a "bill was talked about, and I rather think that it was typed, but I am not sure about that." No bill is extant, but then nor do we have Hansard to check his recollection.

First World War Usage

Tasmania did, however, take part in the Australia-wide use of daylight saving during the First World War. This was enacted by the Parliament in 1916 by a bill, "to promote the earlier use of daylight for certain months yearly." This bill, to introduce Tasmanian Clock Time, was passed quickly, before it was finally repealed in 1917.

The original proposal to "promote the earlier use of daylight in summer" (Bill No.40) was introduced on 1st July 1915. Its "six-months" scheme came under immediate criticism in the House of Assembly. Indeed, Mr C.R. Howroyd (Bass) claimed that he would only withdraw his opposition to the bill (which he saw as a device to extend overtime) if Mr Giblin would consent to have it remitted to a Select Committee for inquiry and report. With the help of Mr A.T. Marshall (Bass) who noted that the better use of daylight "... would lead to a saving of expense for artificial light, would benefit the health of the community, [and] would facilitate the military training of our youths",[6] Mr Giblin was forced to move to establish the Select Committee.

The committee was appointed on 30th September.1915, with the proviso that it report by 2nd November. Nonetheless, during his second reading speech Giblin touched upon an idea that was to become a central element of all later daylight saving arguments:

> "Tasmania was peculiarly suited for innovation of this kind, and should lead the way, just as she has done in electoral matters."

He went on to conclude in the somewhat anglophile manner of the day that:

> "Each new part of the Empire should do something to try to improve our civilization."

The membership of the committee appointed was; Giblin, Barker, Hayes, Howroyd and Marshall. They met on six occasions and interviewed some twenty witnesses. Mr Giblin was appointed the committee's chairman,[7] and he submitted a draft circular to be sent "to 100 representatives of the chief commercial and industrial interests of the state, including most of the industrial unions." The opening paragraph of the circular listed the claimed advantages of the scheme as:

1. Increased time in daylight for recreation.
2. Saving of cost for artificial light.
3. Daylight for military training without trenching [sic] so much on Saturday afternoon.
4. Less use of licensed houses.
5. General benefit to health on account of greater time spent in the open air, and less time in artificially lighted rooms.

The circular also noted that the failure of the scheme in the U.K., despite its favourable parliamentary report, was probably due to "conditions of labour which do not obtain here." In this respect they were referring to the fact that Tasmania had a fairly high number of workers whose hours were controlled by the Arbitration Court at no more than 48 hours per week. Unions overseas feared that the extra hour would lengthen their day but not increase their pay.

Another section of the circular asked all those receiving it to put the matter of daylight saving before their "societies" and document it for the benefit of the committee, noting especially "what difficulties or disadvantages may result from it."

The bulk of evidence received, the committee noted, was "somewhat remarkable [in] that all but three were in favour of the proposal, and two of the three exceptions thought that the change would be good generally though prejudicial to their particular interests." These were mainly "early" workers such as bakers, and woollen mill managers.

The parliamentary report contains a full transcript of evidence taken by the committee, together with several appendices, i.e. letters received by the committee. This makes the report a valuable source of opinion on daylight saving at this time. It is not, however, proposed to quote extensively from it here. Suffice it to say that discussions were held with members of the Department of Education, with shipping firms, Tramways and Railways officials, as well as "private" persons. The result was patently clear. The scheme was in much favour generally, and indeed Mr A.C. Taylor of the Amalgamated Carpenters and Joiners

Association and John Henry O'Neill of the Federated Carters and Drivers Union of Australia (Tas. Branch) declared before the committee that their unions had voted unanimously in favour of the scheme.

In the light of this overwhelming show of support for the idea the committee resolved to recommend the favourable consideration of the bill by the Parliament. This was not, however, until after Mr Howroyd had unsuccessfully moved to have the report reject the whole scheme as premature. He lost a division 2-1, his own versus that of Mr Barker and Mr Marshall, and so the report was presented by Mr Hayes on 23rd December 1915 — a little late, but a Christmas present for daylight saving supporters nevertheless!

The report did make one alteration to the bill for it reduced the time period[8] "by substituting the word 'October' for September because the committee members considered it 'safer' to introduce the change in better weather so that a period of wintery weather would not prejudice the new time at the outset." The main recommendation of the report was:

> "... the advantages claimed for the second proposed change ... are well founded, but that the saving in artificial light would not in Tasmania be of great importance, and that the effect on licensed houses is not very material ... The advantages of the additional hour for out-door recreation seems to be very widely and keenly appreciated ... The provision of daylight for military training is a gain [that] ... will be greatly appreciated both from the military point of view, and (in the case of younger boys) from that of the parents."[8]

In the year following the committee's report the Treasurer, N.E. Lewis, introduced a Daylight Saving Bill (No.19) on Wednesday 2nd August 1916, and it passed the House of Assembly, without amendment, on 16th. In the Legislative Council, however, on 19th September, Mr John Hope (Meander) attempted to adjourn the bill indefinitely, but he lost by a vote of 12:4. His companions in opposition being Messrs Bird, Youl and Dean. The bill gained Royal Assent on 22nd September 1916, as Act No.2, Geo.V, 1916.

On 7th August 1917, Frederick Burbury (Franklin) asked the Premier if the government intended to repeal daylight saving, and he received a negative reply.[9] The government's intention he was told was merely to amend the duration of daylight saving. Thus Burbury introduced his own repeal bill (No.45) on 14th August 1917. Accepting the legislation as timely, the government simply altered it to amend the length of daylight saving and it passed by 12:10 votes on 23rd August.

Following a brief adjournment of the parliament the Legislative Council considered the bill in late September 1917. The passage was not a smooth one, however, for on 25th September a motion to adjourn the bill indefinitely (i.e. to "kill the bill") was moved. This last ditch stand failed and the bill passed and became Act No.8, Geo.V, No.5 (only to be repealed when the war ended by Act No.9, Geo.V, 1919), signed into law on 24th October.

World War Two Usage

Germany was already using daylight saving when the Second World War broke out and the U.S.A. adopted it from 9th February 1942 until 30th September 1945. Australia thus soon followed its allies and reintroduced the scheme, and, as was recalled by Senator Kenneth Anderson (N.S.W.) in 1963, its use was "... based on the war effort and not any concern for the individual."[10]

The Federal Government under Menzies had passed the National Security Act in 1939 and therefore obtained, with qualified Opposition (Australian Labor Party, A.L.P.) support, far reaching war-time powers. Amongst these powers was the right to promulgate regulations on everything from apples, coal and tea, to sheep and the hours of employment. Thus by virtue of the National Security (supplementary) Regulations (Statutory Rule No.28 and No.323a), of 1941, the government introduced daylight saving for all of Australia. It was to be known as "Summer Time", and the important clause of the regulations read as follows:

"(2) Notwithstanding anything contained in any law of the Commonwealth or of any State or Territory, from the hour of two o'clock in the morning of the first day of January, 1942, until the hour of two o'clock in the morning of the last Sunday in March, 1942, summer time shall, in respect of each State and Territory, be one hour in advance of standard time."

However, to save confusion in the armed forced standard time was not be affected for the "purposes of astronomy, meteorology or navigation". And so the regulation stood until September 1942, it was slightly amended by No.393 of 1942.

When the A.L.P. entered government after the collapse of the United Australia Party, the daylight saving scheme was endorsed wholeheartedly. Indeed, John Curtin, the new Prime Minister, is quoted as having said that daylight saving had saved at least 10 000 tons of coal. However, the various State governments at the Premiers' Conferences were soon putting pressure upon Curtain to alter or abandon daylight saving as it was seen as "inconvenient". For example, the Victorian Premier was recorded as saying that 61 of the 71 shires in his State were opposed to daylight saving.[12] Curtin however simply asked the Premiers to put their complaints into written form. But Premier Playford (South Australia), noting that Western Australia had not joined in the 1943 usage, successfully moved at the August 1944 Premiers' Conference in Canberra that daylight saving not be re-introduced for the summer of 1944-45. It was not, and standard time was used for the balance of the emergency regulation period.

John Steer : Daylight Saving Advocate

Because of his great significance to the subsequent history of daylight saving, a brief biographical sketch of Mr John Steer is appropriate.[13] He was born John Leslie Steer on 30th January 1919, at Franklin in southern Tasmania, and worked as a bank officer until the outbreak of the Second World War. During the conflict Steer served in the 2/8 Field Regiment, and tragically lost a leg at El Alamein.

This disability did not deter Steer from re-entering society in an active manner. He originally returned to banking in 1950, and followed this with a period as company representative until 1961. Moreover, Steer contined his associations with sporting bodies, for example, he was to become tournament manager for the Northern Tasmanian Lawn Tennis Association.

Following an unsuccessful attempt to become a member of Parliament in August 1948, Steer's political career, as a member of the Liberal Party, commenced in 1950, when he became a Member of the House of Assembly for Bass in northern Tasmania, where he lived most of his later years. However, his representation of this electorate was not unbroken, for he lost an election in November 1961. After this loss he attempted to gain election for other parliamentary seats, particularly the Legislative Council seat of Cornwall near Launceston. He was finally re-elected as Member for Bass in May 1964, and remained so until his death on 10th October 1968.

Steer's First Attempts

Mr Steer's first bill in late November 1957 aimed to advance the clocks by one hour from the second Sunday in October to the second Sunday in March. The bill was destined to fail, however, from the moment that the Premier, Robert Cosgrove (A.L.P.) chose to describe it as impractical unless implemented on a national basis. Thus the Parliamentary Labor Party voted "en masse" against the bill.

When submitting his bill, however, Steer had said that:

"... it would not cost anybody anything, but it would save money; it would not require the creation of a new government department, nor would it require a horde of civil servants to run it."[14]

Steer managed to gain the support of only two Liberal M.H.A.'s, Messrs Strutt and Townley, and echoing the two-centuries-long debate to gain a "leap year" day, he said that he hoped

"... his bill would live to fight another day, for it was only the first shot in his campaign to get the scheme introduced."[15]

Almost a year later, Mr Steer re-introduced his bill, but this time it failed without even going to a vote in the Chamber. This was because the government had again declared that all its members would vote "en bloc" against it. Steer did find another, and we shall see, valuable friend and ally in Mr W.C. Hodgman (then a Liberal M.H.A. for Denison, later President of the Legislative Council). For during the initial stages of the Bill, Mr Hodgman noted that "farmers were not supposed to be clock watchers", so why should they oppose daylight saving.[16]

Apart from Steer's own suggestion that "daylight saving would add five hours more leisure time to the workingman's week", the most telling point came when the Premier E.E. Reece (A.L.P.) said that of all the correspondence that he had received on the scheme none of it had been favourable to it. The obverse of this course was pointed out by Mr Townley, when he labelled the letter writers as a "vocal minority" and concluded that "the only thing he could see against daylight saving was that it meant a shorter period of sleep for owls!"

The third shot of Steer's campaign, or perhaps more accurately his crusade, took place in November 1959; but it too missed the target. He was able, nevertheless, to gain a small victory when the matter was declared a "non-party" issue in the House of Assembly, thus allowing a free vote with no pressure from the Party Whips on how each member might wish to vote. Even this gain was not sufficient, for on Thursday 19th November, the defeat of the bill was sealed by a vote of 17:11. The 11 supporters being made up of seven of Steer's Liberal colleagues, Mr Wedd an Independent, and two government members. On the other hand, four Liberal party members joined the government against the bill, and Mr McLoughlin (A.L.P.) suggested that it was a suitable topic for a referendum.

W.C. Hodgman's Bills

As noted above Mr Steer was not in the Parliament for the three-year period 1961-1964. Thus it was his friend and ally W.C. Hodgman (by then an Independent Liberal in the Assembly), who introduced on 14th November 1962, his own daylight saving bill. But because of the early Prorogation of the parliament the bill lapsed on 22nd November 1962. Undaunted, and breaking the regularity of a November introduction of the daylight saving bills, Mr Hodgman introduced his second bill on 7th March 1963. During this debate only three M.H.A.'s spoke on the subject: Mr Hodgman naturally was in favour, and Messrs Bramich (Liberal) and Le Fevre (Labor) in opposition. Despite the defeat of the bill it is interesting to note that Mr Hodgman is reported to have said:

> "In view of the results of opinion polls over the years he challenged the Premier to hold a referendum. In answer to the challenge, Mr Reece said outside the parliament that the government had no intention of holding a referendum. It was parliament's place to make a decision on the bill."[17]

Steer Continues His Crusade

John Steer re-entered parliament in 1964 and introduced yet another unsuccessful bill, his personal fourth and the seventh in the campaign. In fact, in September 1964 Steer's fifth bill suffered an even worse fate than the others, for he was the sole speaker. But he was undaunted and his next bill fared better when it was introduced a year later on 24th November 1965, for it at least gained the support of eight Liberals and three Labor members, i.e. 11 votes, only failing by 8 (19:11). This was so because in a surprise move the government, for the second time it must be recalled, allowed a free vote on the issue. During this debate Steer was reported to have claimed (in what is an echo of Willet) that 95% of Tasmanians slept through at least two hours of daylight each morning. But it was Mr Costello (Labor) who was to call for Tasmania to pioneer Steer's scheme. He went on to suggest that "... it was time Tasmania gave the lead to the Commonwealth".[18] However even this 1965 victory was not to be sustained, for in early December 1966, Steer's next bill lapsed because of the lack of any other speakers. It must have been a bitter blow after the apparent success of 1965. However, matters were soon to be reversed.

T.A. Newman

1967 Drought and Power Emergency

Whilst Steer's campaign did not last two centuries as had the "leap year" saga, his battle was valiant nevertheless. It was, however, to be circumstances beyond the control of anyone that produced dividends from his perseverance. In 1967, Tasmania was in the grip of one of its most severe droughts. In the light of the significance of this to the daylight saving scheme, a brief background to the drought is presented here.

In May 1967, *The Mercury* reported that the island was the driest since records had been collected in 1843. Indeed in places only 30% of the average rainfall for the period fell from January to April. Water storage dropped alarmingly, down eventually to less than 20% of capacity. Thus power rationing, which had been used in 1951 (i.e. 25% to all customers), 1955, and again in 1963 (i.e. 15% to industry) was being mooted. Mr Alan Knight, Chief Commissioner of the Hydro-Electric Commission (H.E.C.) warned of a possible 20% cut to industry commencing in October 1967.

Then in early August *The Mercury* (Monday 7th) carried the headling "Save Daylight - Move to Offset H.E.C. Power Cut", and quoted businessmen who felt that the likely saving would be between 2-6% in power consumption. They claimed for example, that it would result in a reduction of lighting for streets and bridges. Mr Bethune even went public the next day, Tuesday 8th, saying that daylight saving "will make a measurable contribution to reducing the normal power consumption."[19]

On this day and after discussions with the H.E.C., Cabinet voted to introduce daylight saving, and the press reports show that this decision was accepted by the Retail Traders' Association unanimously. The H.E.C., in a knee-jerk reaction, stated its fear that a loss of revenue would result from a reduction in use. And by 22nd September, Mr Knight is reported as saying that whilst daylight saving may produce a saving, it "may save less than 1%". A New Zealand car-ferry, the *"Hinemoa"*, was brought to Tasmania to act as an off-shore power generator, and the H.E.C. was forced to make a decision to build an oil-fired power station at Bell Bay, where another steam turbine ship, the *"George H. Evans"* was already moored.

Steer Succeeds

This emergency caused the Labor government to suspend the normal rules of parliamentary procedure so that Mr Steer, a Liberal, could introduce a bill (No.47) on 22nd August, and have it passed the next day. The debate for Mr Steer must have been a dream, and he noted that "it was a very painless way of saving power." The Legislative Council received the bill on 12th September (the 164th anniversary of the landing by Lt Bowen in Tasmania) and passed it immediately, although with amendments. The main amendment being that King Island was to be excluded from the scheme because its economy was more closely tied to that of the mainland than that of Tasmania. The Hon. J.R. Orchard (Launceston) also tried twice to have the bill amended by deleting first the idea that the clocks be advanced, and second that its title be dropped; both of these last ditch attempts failed. Thus the bill went forward to the Governor for Royal Assent, which it gained on 22nd September, and became Act No.33 of 1967. Its preamble was quite specific and declared that it was:

> "An Act to promote the greater use of daylight in certain months of the years 1967 and 1968, in order to reduce the usage of electric power during the present shortage ..."

Permanent Daylight Saving

The emergency, of course, ended in both legislative and power rationing terms. Then in May 1968, after returning from an interstate trip promoting daylight saving, Mr Steer was again given permission to introduce a bill (No.26) for permanent use of the scheme. A significant point of interest is that far from lacking a seconder there were 14 other speakers on the bill from both sides of the parliament. From the press reports we can detect that the bill passed readily through the House of Assembly, but that a deadlock developed between the two houses of parliament before the bill could become law.

The House of Assembly finished with the bill on 28th May 1968, but the Council was to make certain amendments to it that the Assembly would not accept, although it would accept a change in name from "Tasmanian Clock" to "Tasmanian Summer" Time. The Assembly would not reduce its plan for five months to only four months, nor would it accept that a further trial period be undertaken.

The Councillors representing rural electorates were not sympathetic to the scheme. For example, Mr Lloyd Carins (South Esk) claimed that only some 30% of the island's population favoured the idea. His colleague Mr Michael Hodgman (Huon), however, suggested that 85% would be more in the vicinity of public support. Nonetheless, on 13th June 1968, with the aid of a vote of 9:6 votes Mr Carins gained the establishment of a Select Committee to review the bill. The membership of the committee was: Mr Carins, together with Messrs Hodgman, Lowrie, Best and Orchard.

Mr Carins was elected chairman when the committee met briefly on 13th June 1968. The committee's work then went on to include some seventeen meetings held in Hobart, Launceston, Deloraine, Devonport and Burnie, and heard some two hundred witnesses, ten times as many as in 1915.

The committee was subjected to a wide range of opinion for and against the scheme from such groups as the Archery Society of Tasmania, Devonport Tennis Club and the Education Department. They in turn questioned all witnesses concerning their views on the duration of the scheme. As their report notes, "The most cogent arguments advanced by supporters of daylight saving legislation lie in the fields of leisure and recreation." Such comments having arisen from evidence given by many sporting organisations, the National Fitness Council and St Johns Park Hospital. "In summary", the committee reported, "it became clear from evidence considered that the greatest argument to support daylight saving is the organisation of time for the benefit of man."[21]

However, in presenting a fair and balanced report they did note the adverse opinions of many agricultural industries, and, for example, those of the cinema industry, especially the reduced patronage of drive-in theatres, said to have been some 31% down in 1967-68. They also presented, *inter alia*, a summary of disadvantages of daylight saving submitted in evidence:

"General effect on primary producers, their wives and families:

1. The necessity to rise in darkness over a longer period.
2. A longer working day.
3. Considerable inconvenience to mothers of school children who travel by bus.
4. Difficulty in settling over-tired children in daylight in warm rooms.
5. Housewives in many cases obliged to prepare two evening meals.
6. Family as a whole feel the strain of long hours.
7. Over-tiredness affected efficiency.
8. Social activities and meetings inconvenienced."[22]

Nevertheless, after having noted that the "period of daylight saving in 1967-68 has indicated little economic benefit to the state", the committee determined that permanent daylight saving was more favoured in the urban than in the rural sectors of society. Therefore, their major recommendation, which was based upon a resolution moved by Mr Hodgman, was as follows:

"(1) That daylight saving be introduced for a further trial period of two years from the first Sunday in November to the first Sunday in March."

The Council on 17th September, communicated its resolutions to the House of Assembly. Mr K. Lyons totally agreed with all the Council's amendments, but the Assembly "felt it to be its duty to disagree for the following reasons" which were compiled by Messrs Neilson (A.L.P.), and Mather and Young (Liberal).

"(1) Because the amendments would create a substantial imbalance between the number of days on which Daylight Saving would operate before and after the longest day of the year.

(2) Because the period incorporated in the bill from the second Sunday to a second Sunday is more convenient and less likely to create public confusion than the period proposed by the Amendment.

(3) Because there is evidence of strong public preference for the period of Daylight Saving (originally) proposed in the Bill.
(4) Because there is no need for a time limit on the operation of the Bill..."

The Legislative Council's reaction to this message was to establish a reasons committee of its own, and after a brief twenty minute suspension of the sitting, Messrs Carins, Best and Lowrie reported their deliberations to the Council. Thus the Council sent a further message to the Assembly stating that all its amendments were acceptable to a majority of the Tasmanian people and therefore stood. They would also "allow daylight saving during the recognised period of Summer and would cause the least inconvenience to the community and school children."

Naturally, the Assembly's position had not changed in this short time, and thus it called for a conference of managers; i.e. four members from each chamber meeting in secret in an attempt to reach a compromise. These managers, namely, Carins, Lowrie, Best and Fenton for the Council, and Neilson, Cashion, Mather and Young for the Assembly, met on 19th September. After nearly two hours of discussion they could not alter the resolve of either chamber, except that the Council take its amendments into further consideration, which it did.

Despite an attempt by Mrs P. Benjamin (A.L.P., Hobart) to have the Council relax its views, the final message to the Assembly read in part:

"... while the Council accepts the idea of Daylight Saving it finds that the Assembly ignores the effects of it upon the rural community, and besides, the Council's amendment was *not* an impractical suggestion."[23]

The Assembly decided to accept the amendment leading to a further two-year trial period but would not relax its original plan for five months of daylight saving. It is a point of interest here to note that *The Mercury* reported that Mr R. Mather (Liberal, Denison) was handling the Bill on Mr Steer's behalf because he was ill at the time - he was to die in October of that year. The Council, as a whole, were able to compromise on an additional two weeks to the duration of the scheme. This was not without a division being required, with Mr Carins, McFie, Bisdee, Gregory, Best and Fenton being defeated in a 10:6 vote.

When this decision reached it, the Assembly was still in a mood to stand firm for five months, but in order that no further delay would put the coming summer usage of daylight saving in jeopardy the Assembly accepted the two weeks offered by the Council. In the words of Mr Mather, this was done "with considerable regret" and because "I think they [the people] would want it for four and a half months rather than not have it at all."[24] The bill passed this final stage on the voices without a division being required, it gained the Royal Assent on 15th October, and became Act No. 42/1968. Thus the Tasmanian public, including those on King Island, were either to enjoy or endure a further period of daylight saving.

In September 1969, the recently elected Premier Angus Bethune (Liberal) went public saying that he thought that overall the benefits of daylight saving outweighed the inconvenience and therefore, he thought that it was "here to stay". Moreover, he felt that it was approved by the overwhelming majority of Tasmanians, not to mention tourists, and that any argument for a referendum was rejected as unnecessarily expensive.[25]

While he was Acting Premier, Mr Lyons. the Deputy Premier and sole Centre Party member in the coalition government, introduced the second reading of the daylight saving bill on 4th June 1970. This bill was to establish the permanency of the scheme, and it is interesting to note that once more over a dozen speakers took part in the debate. When the Legislative Council debated the bill, however, *The Mercury* reported that an "onslaught" against it was led by Mr Lloyd Carins and backed by Mr L. Bisdee (Monmouth) and Mr Charles Fenton (Russell).

An attempt by Mr Carins, during what was a nine hour debate, to institute yet another two year trial failed by 8:6 votes, and so the daylight savings scheme was enacted for a permanent four and one half month annual period. The bill actually gained Royal Assent on 30th June 1970, and became Act No. 20/1970.

About Time — Daylight Saving in Tasmania

Interstate Usage Affects Tasmania

It is at this stage in the history of daylight saving that the Australian usage returned to the fore. The Tasmanian usage of daylight saving had been noted on the mainland and had indeed been a catalyst, for example, in the establishment of a Daylight Saving Association in New South Wales, which commenced lobbying in 1968. Moreover, in each State parliament, and in the various State communication media daylight saving debates raged much as they had in Tasmania, but not for nearly as long. During a debate in the Australian Senate, Senator K. Anderson, whom we have already quoted produced a photostat copy of an unnamed newspaper dated 10th January 1956 reporting that Robert Menzies had claimed that he had "never understood arguments against daylight saving."[26]

At a meeting of Chief Secretaries in July 1971, Mr K. Lyons, who had negotiated with the other States, agreed to bring in a bill to enforce the reduction by two weeks in the daylight savings period for Tasmanian Summer Time. This was so that all the eastern States would adopt a common four months period. Moreover, this initial period was to include Queensland and Western Australia. During the debate on the reduction, the Tasmanian government came under fire for being forced to back down by the other States, especially by the larger States of Victoria and New South Wales. The Legislative Council passed the bill for the reduced term om 3rd November 1971, although many M.L.C.'s had stated their distaste for the backdown because Tasmania had pioneered the scheme. The bill gain Royal Assent on 26th November and became No.71/1971..

Because there was a change of government in Tasmania in December 1971, and the A.L.P. returned to power, Mr Neil Batt (A.L.P., Denison) attended the July 1972 meeting of Chief Secretaries. Then in October, the House of Assembly approved, without dissent, a bill (No.65) to adjust the period of daylight saving in Tasmania. In contrast to the lengthy debates of the 1960's, and the "non-debates" earlier still, the Assembly took just fourteen minutes to save the one hour this time for eighteen weeks. This swift compromise, to again conform with the mainland States was nevertheless only reluctantly accepted. Indeed, Max Bingham, the Leader of the Opposition, said that his party's support was "tinged with sadness".[27] In the Legislative Council the bill passed without amendment, and it gained Royal Assent on 9th November 1972 as Act No.25/1972.

Speaking on radio on 20th October 1974 the Tasmanian Premier Eric Reece (A.L.P., Wilmot) said that daylight saving had gained nearly universal acceptance, so much so that the first Sunday in October was now a memorable event in each year. He went on to say that daylight saving "brought a new dimension to the leisure hours of the day and early evening". He concluded by suggesting that "perhaps the Australian Government might be prepared to have a look at the question to see what could be done on a national basis..."[28]

We shall return to the national sphere shortly, but it seems worthy to quote a passage from *The Mercury* editorial of 28th February 1975, to capture the prevailing Tasmanian thoughts on daylight saving:

> "Certainly there would be few of the 50,000-odd eastern shore commuters who would not welcome an extra hour of daylight for the drudgery of their evening ordeal in getting from one side of the Derwent to the other." [The Tasman Bridge was partially destroyed when the vessel *Lake Illawarra* collided with it on 5th January 1975.][29]

Duration Debate

The Tasmanian Apex Clubs supported the extension of daylight saving from four and a half to five months, but on 21st September 1976 Premier Neilson told the House of Assembly that neither Tasmania nor the rest of the eastern States would be extending the period of daylight saving.

Two years later during February-March 1978, the Tasmanian Tourist Council again advocated an extension of daylight saving for at least six months. They based their stand upon a survey they had conducted of their 500 members which showed that some 44% would prefer, for marketing reasons especially, six months daylight saving, while a further 31% wanted

year-round daylight saving, with the remaining 25% opting for the existing four months as sufficent.

Premier Doug Lowe (A.L.P.) felt that he was prepared to take the extension of daylight saving to the next Premier's Conference but that Tasmania "could not go it alone."[31] Rural groups, especially in northwestern Tasmania sought to block the extension of daylight saving, and also the Returned Servicemen's League wrote to the Minister for Tourism, who was a known advocate of the six months extension, saying "they would rather not have it [daylight saving] but we accept the present situation" and they would be prepared to "fight to prevent it going any further".[32] Mr V.L. Kelly of the Tasmanian Farmers' Federation told Premier Lowe that its policy was to oppose the extension of daylight saving, and in fact West Tamar farmers, at a meeting on 21st March 1979, directed their leaders to campaign against daylight saving. For example, the Women's Temperance Union, at its 87th Annual State Conference, came out against the whole idea of daylight saving because it caused the young to stand and wait for school buses in the dark.[33]

In March 1980 the Frederick Henry Bay Apex Club promoted and 36 other Apex Clubs circulated some 700 daylight saving petitions which were presented to the State government. The Minister for Tourism, Mr Barnard, was in favour of this action. Moreover, the Minister for Recreation, Mr Holgate, on 4th July, was also presented with a petition from private citizens of Launceston with some 7 000 signatures in favour of daylight saving. However, a counter petition containing 451 signatures was tabled by Mr Cornish (Liberal, Wilmot) on 14th July 1980, from citizens of the northwestern part of the State, a major rural area of Tasmania. They rejected daylight saving because of "the disruption" it [already] "caused to the lives of our children and ourselves."[34]

Cabinet, at a meeting on 18th February, and at another on 24th February were unable to decide on a common day for commencement and conclusion of daylight saving. Thus Cabinet passed the decision on to the A.L.P. Caucus because in Mr Lowe's words:

> "... the more we discussed an extension, the more there seemed to be sensible variations to the period proposed."[35]

On 4th March, Premier Lowe announced that Caucus had decided to extend daylight saving to commence in the first weekend in October to the last weekend in March 1982.

Once more the Tasmanian Farmers' Federation voiced strong opposition to the extension of daylight saving, with the President Mr J.G. Allwright saying that "Cabinet's decision to extend daylight saving meant increased costs for farmers and problems with obtaining labour", not to mention the problems it caused for mothers and school children.

The bill to achieve this extension was introduced to the Legislative Council by Mr Miller on 19th March 1981, but it was rejected without a vote, after a debate that had lasted just one and a half hours. There had been 13 M.L.C.'s speaking against it.[36]

The government revived the bill in the House of Assembly on 8th September 1981. In late August the Liberal Party at its State Party Conference, had rejected a motion to oppose daylight saving and instead allowed an open or free vote. The Tasmanian Tourist Council was opposed in its support of daylight saving by, for example, the Dairy Council, while the Queenstown Council planned to write to every M.L.C. advocating rejection of the bill.

But the delay in introducing the bill meant that the government itself was forced to alter the duration of the period of daylight saving. Because the legislation could not possibly be passed by 23rd September, daylight saving would have to start on the first Sunday in October. On 24th September, the bill did manage to pass in the Assembly, through a free vote by the Liberals in which seven members of that party supported the government. As a result the vote was a 24:8 majority in favour.

On 14th October 1981 the Legislative Council did pass the bill for the extension of daylight saving by a vote of 9:7. They not only shortened the period yet further, but also introduced a "sunset" clause into the bill. Sunset clauses, although the name is well suited to daylight saving bills, in effect meant that the legislation would expire on

the date so inserted, that is, another two year trial period was commenced.[37] Instead of the extra six weeks originally planned, only three weeks were gained, and even these would expire in March 1983. By then, according to the theory put forward by Mr Peter Hodgman (M.L.C., Huon) who moved the sunset clause, "facts rather than hypothesis could be produced by opponents of the extension."[38] The House of Assembly agreed to these amendments on 21st October 1981, just in time for the season of daylight saving to begin on that coming Sunday morning.

The public realised that the extra hour extended three weeks beyond that operating in the other States and also discovered that their television and radio shows were out of synchronisation, as were airline and postal schedules. These discoveries created personal problems for both public and parliamentarians and militated against the extension for three weeks. Nevertheless the Gray Liberal Government introduced a bill in April 1983 intended to prevent the expiration of the daylight savings extension. It was debated quickly in the Assembly and passed onto the Legislative Council on 3rd May, were more petitions were tabled against the scheme. The intentions of the Legislative Council were soon clear for the tenor of debate was mainly negative.[39] Once again the rural lobby had won the day and persuaded the Councillors to defeat the bill; they did so on the 4th May by 8:4 votes. Thus at the time of writing, Tasmania still operates a permanent scheme of daylight saving albeit of a shorter period than that desired by the government.

CONCLUSION

This history of daylight saving in Tasmania has concentrated upon the events surrounding it rather than upon the endless repetition of views for or against the scheme. Such views are numerous and well known, and need not be aired here. It is hoped that this factual approach has been able to capture the slow chronological movement towards daylight saving, from its early associations with war to its widespread use in peace time. Moreover, it is hoped that the setting down of a substantial portion of the Tasmanian history of daylight saving has been of some service in documenting the innovative role that this State has played in the use of daylight saving. On this last point, an editorial from *The Mercury* has an apt comment:

> "It took 11 years of frustration, even ridicule, for John Steer's brainchild to become accepted as a worthwhile amenity. And its acceptance by most States was only because Tasmania showed unusual fortitude to pioneer and persevere."[40]

Further quotations might be made from the Bible (see Ecclesiastes ch.3, 1-18) or from any of the authors who have dealt with the theme of time and man (e.g. T.S. Eliot, James Joyce, Shakespeare) but space does not permit them. Nevertheless, it seems appropriate to quote a general item that encapsulates the essence of the interaction between time and man. George Kubler, an American art historian, has this to say:

> "Time, like mind, is not knowable as such. We know time only indirectly by what happens in it."[41]

In other words, it is the use that we make of the "extra" time granted by daylight saving that gives it its best support.

ENDNOTES

1. See Jesperson, J. and Fitz-Randolph, J., 1979: TIME AND CLOCKS FOR THE SPACE AGE. New York, Atheneum: 16-17 & 32-33.
2. Quoted in Report of the Select Committee Upon the Saving of Daylight, Victoria. Parliamentary Paper No.D5, Vol.1, 1909.
3. One of the better analyses of certain aspects of this nexus is Geoffrey Blainey's TYRANNY OF DISTANCE, 1966, Sun Books, Melbourne: 2-15 and passim.
4. See Rosenhain, M., 1972: A land of lots of time ... *Walkabout*, January 1972: 55-57.
5. Both quotations below appear in the report to the Tasmanian Parliament, Parliamentary Paper No.77/1894: 4.
6. The following quotations all appear in *The Mercury's* section on parliamentary affairs 23rd September 1915 and 30th September 1915.
7. See Parliamentary Paper No.55/1915.

8. *Ibid.*: ii.
9. Votes and Proceedings of House of Assembly, 7th August 1917.
10. *Senate Debates*, 1963, vol.S24: 39-70.
11. Statutory Rule No.28 and No.323, 1941: 770-771.
12. See Victorian Hansard, 5th October 1971, vol.303: 995.
13. See Bennett, S. & Bennett, B., 1980: BIOGRAPHICAL REGISTER OF THE TASMANIAN PARLIAMENT, 1851-1960, A.N.U., Canberra: 155.
14. *Mercury Reprints*, 22nd November 1957: 53.
15. *Mercury Reprints*, 28th November 1958: 60.
16. *Mercury Reprints*, 28th November 1958: 60.
17. *Ibid.*, 15th March 1963: 32.
18. *Ibid.*, 2nd July 1964: 10
19. *The Mercury*, 8th August 1967: 1.
20. See Newman, T.A., 1977: THE TASMANIAN LEGISLATIVE COUNCIL: ITS COMMITTEE SYSTEM, 1927-1976. University of Tasmania B.A. (Hons.) thesis: 60-64.
21. Parliamentary Paper No.41/1968.
22. *Ibid.*
23. Votes and Proceedings of Legislative Council: 126.
24. *Mercury Reprints*, 3rd October 1968.
25. *The Mercury*, 26th September 1969 and 5th December 1969.
26 *Senate Debates*,
27. *Mercury Reprints*, 6th October 1972: 28.
28. *The Mercury*, 30th July 1974.
29. *The Mercury*, 28th February 1975.
30. *The Mercury*, 8th March 1978.
31. *Ibid.*, 22nd March 1978.
32. *Advocate*, 23rd March 1978.
33. *The Mercury*, 27th March 1979.
34. *Advocate*, 15th July 1980.
35. *The Mercury*, 25th February 1981.
36. *The Examiner*, 9th March 1981.
37. See Legislative Council Hansard, 1981, Vol.III, No.1: 605-655.
38. *The Mercury*, 15th October 1981.
39. See Legislative Council Hansard, 4th May 1983: 291-326.
40. *The Mercury*, 4th May 1976.
41. Quoted in Brockman, J. & Rosenfeld, E., 1973: REAL TIME, Picador/Pan, London: 69.

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A LIST OF THE TYPE SPECIMENS OF BEETLES (COLEOPTERA) IN THE COLLECTION OF THE TASMANIAN DEPARTMENT OF AGRICULTURE

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ABSTRACT

McQUILLAN, P.B., 1984 (31 viii): A list of the type specimens of beetles (Coleoptera) in the collection of the Tasmanian Department of Agriculture. *Pap. Proc. R. Soc. Tasm.*, 118: 37-45. ISSN 0080-4703. Tasmanian Department of Agriculture, G.P.O. Box 192B, Hobart, Tasmania 7001.

This paper provides an annotated list of the type specimens of 192 species of beetles in the collection of the Tasmanian Department of Agriculture in Hobart. All the types are paratypes. The majority are from the collection of A.M. Lea who was Government Entomologist from 1899 to 1911. Paratypes of species described by A. Neboiss and B.B. Given are also represented and there is one type attributed to A. Raffray.

INTRODUCTION

The insect collection of the Tasmanian Department of Agriculture is maintained at the New Town Research Laboratories, near Hobart. Currently it comprises some 20 000 pinned specimens in 60 metal units each holding 10 glass-topped drawers, about 12 000 specimens in liquid preservative, and about 10 000 specimens mounted on microscope slides. Groups particularly well represented include Coleoptera, Collembola, Aphidae, Coccoidea and insects of economic importance.

Serious collecting began in 1899 with the appointment of Arthur M. Lea as Government Entomologist to succeed Tasmania's first Government Entomologist, the Rev. Edward H. Thompson. Lea was a meticulous observer and collector of insects. He was interested predominantly in beetle taxonomy and published extensively on beetles from 1893 until his death in 1932 (Hale 1932). Over this period he described more than five and a half thousand new species. His valuable and meticulously prepared collection of several hundred thousand beetles graces the South Australian Museum, Adelaide, where he was entomologist from 1911 until his death.

Lea travelled widely in Tasmania and visited many areas made accessible only by mineral developments on the West Coast. In addition, he received material from a range of correspondents such as Augustus Simson, a Launceston stockbroker. Upon leaving Tasmania in 1911 to take up a position as entomologist at the South Australian Museum, Lea took with him most of his extensive beetle collection. However, he left in the Tasmanian Department of Agriculture a labelled collection of Tasmanian and other Australian beetles, including paratypes of 189 species he had described.

In addition, the Department's collection houses paratypes of beetles described by A. Neboiss, B.B. Given and A. Raffray.

The purpose of this paper is to provide an annotated list of the type specimens held by the Tasmanian Department of Agriculture so that future workers may have access to this previously neglected material.

In this list, the information provided is arranged as follows:

Column 1 - The families cited follow Britton (1970) and are arranged alphabetically. Species within each family are also arranged alphabetically, the author and date of publication being noted.

Column 2 - The genus to which the corresponding species in Column 1 was originally assigned is shown.

Type Specimens of Beetles, Tasmanian Department of Agriculture

Column 3 - Information obtained from the labels is shown; on the first line the State of origin and the status of the specimen (on hand-written labels), on the second and subsequent lines any information on the small usually printed labels attached to the pin bearing the specimen.
Column 4 - The number of specimens is recorded.

ANISOTOMIDAE			
bicoloriclava Lea, 1912a	*Anisotoma*	Tasmania. Cotype Frankford, Tas.: Lea	1
APIONIDAE			
aterrimus Lea, 1910e	*Auletes*	N.S.W. Cotype	1
australasiae Lea, 1910f	*Apion*	Tasmania. Cotype Swansea, Tas.: Lea	1
decipiens Lea, 1910e	*Auletes*	Tasmania. Cotype Huon R., Tas.: Lea	1
horni Lea, 1910e	*Tychius*	N.S.W. Cotype Forest Reefs, N.S.W.: Lea	1
imitator Lea, 1910e	*Auletes*	Tasmania. Cotype Huon R., Tas.: Lea	1
inconstans Lea, 1910e	*Auletes*	Tasmania. Cotype Mt Wellington, Tas.: Lea	1
microscopicum Lea, 1910e	*Apion*	Tasmania. Cotype	1
nigrosuturale Lea, 1910e	*Apion*	NW Australia. Cotype	1
punctipennis Lea, 1910e	*Auletes*	Victoria. Cotype Bullarook Forest, Vic.	1
stilbum Lea, 1910e	*Apion*	N.S.W. Cotype	1
subcalceatus Lea, 1910e	*Auletes*	Tasmania. Cotype Hobart, Tas.: Lea	1
subopacum Lea, 1910e	*Apion*	Queensland. Cotype	1
tasmanicum Lea, 1910e	*Apion*	Tasmania. Cotype	1
variicollis Lea, 1910e	*Auletes*	Tasmania. Cotype Stonor, Tas.: Lea	1
vertebrale Lea, 1910e	*Apion*	N.S.W. Cotype Ourimbah: Ferguson	1
BELIDAE			
inconstans Lea, 1908c	*Belus*	Queensland. Cotype Brisbane: McGregor	1
nigriceps Lea, 1908b	*Belus*	N.S.W. Cotype Armidale, N.S.W.: Lea	1
pictirostris Lea, 1908c	*Belus*	Cotype Hobart: Griffith	1
CARABIDAE			
lineatus Lea, 1908a	*Scopodes*	King Island. Cotype King Is., Tas.: Lea	2
troglodytes Lea, 1914	*Idacarabus*	Tasmania. Cotype Ida Bay Caves	1
CIIDAE			
tasmaniae Lea, 1910c	*Tritomidea*	Tasmania. Cotype Parattah, Tas.: Lea	1
CLERIDAE			
curvifasciata Lea, 1910b	*Allelidea*	W. Australia. Cotype	1
nigrovaria Lea, 1907b	*Lemidia*	King Island. Cotype King Is., Tas.: Lea	1
pictipes Lea, 1908a	*Apteropilo*	King Island. Cotype	1

subsuturalis Lea, 1907b	*Lemidia*	Tasmania. Cotype Mole Ck, Tas.: Lea N3 3007 Mt Wellington, Tas.: Lea	2
COCCINELLIDAE			
blackburni Lea, 1908a	*Rhizobius*	Tasmania. Cotype Hobart, Tas.: Lea	1
corticalis Lea, 1908a	*Scymnus*	Tasmania. Cotype New Norfolk, Tas.: Lea	1
nigrovarius Lea, 1908a	*Rhizobius*	King Island. Cotype	1
CRYPTOPHAGIDAE			
troglodytes Lea, 1914	*Cryptophagus*	Cotype	1
CUCUJIDAE			
walkeri Lea, 1904a	*Dryocera*	Cotype Huon R., Tas.: Lea 1919	2
CURCULIONIDAE			
abundans Lea, 1910e	*Acacicis*	Tasmania. Cotype. Hobart, Tas.: Lea	1
acaciae Lea, 1910e	*Phloeopthorus*	Tasmania. Cotype Hobart, Tas.: Lea	1
alboscutellaris Lea, 1911d	*Poropterus*	Tasmania. Cotype Frankford, Tas.: Lea	1
alleni Lea, 1910e	*Eurychirus*	Queensland. Cotype Cairns: E. Allen	2
ammophilus Lea, 1909	*Mandalotus*	N.S.W. Cotype	1
amplicollis var A Lea, 1906a	*Misophrice*	Tasmania. Cotype Hobart, Tas.: Lea	1
angophorae Lea, 1906a	*Baris*	N.S.W. Cotype	1
angustipictus Lea, 1911c	*Mandalotus*	Tasmania. Cotype Stanley, in tussocks top of Nut.	1
angustus Lea, 1911d	*Pyrpnus*	N.S.W. Cotype Mt Victoria, N.S.W.: Lea	1
apicigriseus Lea, 1908a	*Brachyporopterus*	King Island. Cotpye King I., Tas.: Lea	1
arrowi Lea,. 1911d	*Lipothyrea*	Queensland. Cotype	1
australiae Lea, 1906a	*Baris*	N.S.W. Cotype	1
blackburni Lea, 1911d	*Eristus*	Cotype Mt Wellington, Tas.: Lea	1
blackburni Lea, 1907c	*Mandalotus*	Cotype Jordan R., Tas.: Lea	1
blackmorei Lea, 1907c	*Mandalotus*	N.S.W. Cotype	1
boviei Lea, 1911d	*Echrizothis*	Victoria. Cotype	1
brevirostris Lea, 1908c	*Pantorietes*	Victoria. Cotype	1
bryophagus Lea, 1908b	*Elleschodes*	Tasmania. Cotype	1
campylocnemis Lea, 1904b	*Mandalotus*	N.S.W. Cotype	1
carinativentris Lea, 1907c	*Mandalotus*	Tasmania. Cotype Swansea, Tas.: Lea	1
caviventris Lea, 1908a	*Mandalotus*	King Island. Cotype	1
cinerascens Lea, 1906b	*Leptops*	Queensland. Cotype Dalby, Q.: Mrs F.H. Hobler Darling Downs F	2
conifer Lea, 1910f	*Onesorus*	N.W. Australia. Cotype	1
conloni Lea, 1908a	*Perperus*	Cotype	1
costirostris Lea, 1908a	*Perperus*	King Island. Cotype	1
decipiens Lea, 1908c	*Elleschus*	W. Australia. Cotype Swan R.: Lea	1
decipiens Lea, 1910e	*Merimnetes*	Tasmania. Cotype Hobart, Tas.: Lea	1

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echinata Lea, 1908b	*Hibberticola*	S. Australia. Cotype	1
elegans Lea, 1911c	*Rhinaria*	Tasmania. Cotype Jordan R., Tas.: Lea	1
elongatus Lea, 1910e	*Notoplatypus*	N.S.W. Cotype	1
eucalypti Lea, 1908a	*Elleschodes*	King Island. Cotype King I., Tas.: Lea	2
fasciculatus Lea, 1906b	*Leptops*	Queensland. Cotype Cairns, N. Queensland	1
gloriosa Lea, 1906a	*Misophrice*	Tasmania. Cotype	1
granicollis Lea, 1911c	*Timareta*	W. Australia. Cotype	1
hobleri Lea, 1911c	*Misophrice*	Queensland. Cotype Dalby: Mrs F.H. Hobler	1
inconstans Lea, 1911d	*Eristus*	Tasmania. Cotype Mt Wellington, Tas.: Lea	1
inconstans Lea, 1909	*Timareta*	Tasmania. Cotype Hobart, Tas.: Lea	1
inermis Lea, 1909	*Magdalis*	N.S.W. Cotype Forest Reefs, N.S.W.: Lea	1
intermixta Lea, 1909	*Timareta*	Tasmania. Cotype	1
interocularis Lea, 1911c	*Mandalotus*	Tasmania. Cotype	3
interstitialis Lea, 1911b	*Pelororhinus*	N.S.W. Cotype Liverpool 12.10.99 WWF	1
inusitatus Lea, 1907c	*Mandalotus*	Tasmania. Cotype Hobart, Tas.: Lea	1
latipennis Lea, 1910f	*Prosayleus*	W. Australia. Cotype	1
litoralis Lea, 1908a	*Conlonia*	Cotype	1
litoralis Lea, 1911c	*Perperus*	Tasmania. Cotype Ulverstone, Tas.: Lea	1
maculatus Lea, 1908a	*Mandalotus*	Tasmania. Cotype Hobart, Tas.: Lea 1776	1
major Lea, 1908a	*Decilaus*	King Island. Cotype King Is., Tas.: Lea	1
mamillatus Lea, 1909	*Magdalis*	Victoria. Cotype	1
maritima Lea, 1911d	*Sediantha*	W. Australia. Cotype	1
melancholicus Lea, 1911d	*Poropterus*	King Island. Cotype King I., Tas.: Lea	1
minimus Lea, 1910e	*Haplonyx*	N.S.W. Cotype Mt Victoria, N.S.W.: Lea	1
mirabilis Lea, 1911d	*Myllocerus*	N.W. Australia. Cotype N.W. Australia	1
mixta Lea, 1908a	*Phlaeoglymma*	King Island. Cotype King I., Tas.: J.A. Kershaw	1
mollis Lea, 1908a	*Decilaus*	King Island. Cotype King Is., Tas.: Lea	1
montanus Lea, 1911d	*Haplonyx*	Mt Kosciusko. Cotype	1
montanus Lea, 1910e	*Merimnetes*	Tasmania. Cotype	1
multinodosus Lea, 1906b	*Leptops*	N.S.W. Cotype	1
muscivorus Lea, 1909	*Mandalotus*	Tasmania. Cotype Waratah, Tas.: Lea in moss and lichens.	1
neglectus Lea, 1908c	*Stenocorynus*	Queensland. Cotype	1
nigripes Lea, 1906a	*Misophrice*	Tasmania. Cotype Hobart, Tas.: Lea	1
nigropunctatus Lea, 1906a	*Leptops*	N.S.W. Cotype Carrathool	1
nigrovarius Lea, 1909	*Omorophius*	W. Australia. Cotype	1
nociva Lea, 1909	*Desiantha*	Victoria. Cotype	1
nodicollis Lea, 1907c	*Mandalotus*	Queensland. Cotype Darling Downs F	1
pallidus Lea, 1908a	*Eristus*	King Island. Cotype	

phymatodis Lea, 1906b	*Leptops*	Queensland. Cotype Cairns	1
pini Lea, 1911d	*Car*	Tasmania. Cotype Swansea, Tas.: Lea	1
pretiosa Lea, 1911d	*Lybaeba*	Victoria. Cotype	1
punctícollis Lea, 1909	*Timareta*	Tasmania. Cotype	1
pygmaeus Lea, 1908a	*Microcryptorhynchus*	King Island. Cotype	1
regularis Lea, 1906b	*Leptops*	N.S.W. Cotype N.S.W., Coolabah	1
rotundata Lea, 1910f	*Cassythicola*	W. Australia. Cotype	1
rufimanus Lea, 1908c	*Elleschodes*	N.S.W. Cotype	1
rufimanus Lea, 1908b	*Magdalis*	Tasmania. Cotype	1
sabulosa Lea, 1908a	*Achopera*	Tasmania. Cotype Ulverstone, Tas.: Lea	1
salrilosus Lea, 1907c	*Mandalotus*	Tasmania. Cotype	2
scrobiculata Lea, 1908b	*Wiburdia*	N.S.W. Cotype Vicinity of Jenolan Caves: J.C. Wiburd	1
semiporosus Lea, 1908c	*Melanterius*	Queensland. Cotype	1
simplicipennis Lea, 1910e	*Merimnetes*	Tasmania. Cotype Hobart, Tas.: Lea	1
sobrinus Lea, 1908a	*Decilaus*	King Island. Cotype King I., Tas.: Lea	1
squamiventris Lea, 1906a	*Misophrice*	Tasmania. Cotype Hobart, Tas.: Lea	1
subcaerula Lea, 1908a	*Eniopea*	King Island. Cotype King I., Tas.: Lea	1
sublineatus Lea, 1911c	*Prosayleus*	N.S.W. Cotype Forest Reefs, N.S.W.: Lea	1
subopaca Lea, 1906a	*Baris*	N.S.W. Cotype	1
swanseaensis Lea, 1909	*Timareta*	Tasmania. Cotype	1
tasmaniensis Lea, 1911c	*Acantholophus*	Freycinet Peninsula, Tasmania Hobart, Tas.: Lea	2
tasmaniensis Lea, 1908a	*Roptoperus*	Hobart, Tas.: Lea Devonport, Tas.: Lea	2
tenuirostris Lea, 1911c	*Elleschodes*	Tasmania. Cotype	1
tenuis Lea, 1911d	*Eniopea*	W. Australia. Cotype Vasse	1
tibialis Lea, 1911b	*Methypora*	Queensland. Cotype	1
tibialis Lea, 1911c	*Pyrpnus*	S. Australia. Cotype Venus Bay, S. Australia	1
tibialis Lea, 1908b	*Sellechus*	N.S.W. Cotype	1
trifasciata Lea, 1911d	*Lybaeba*	Victoria. Cotype	1
tropicus Lea, 1911d	*Laemosaccus*	Queensland. Cotype Cairns	1
tuberculatus Lea, 1911c	*Mythites*	Victoria. Cotype	1
uniformis Lea, 1911c	*Elleschodes*	Tasmania. Cotype Hobart, Tas.: Lea	1
vacillans Lea, 1907c	*Mandalotus*	Tasmania. Cotype 1303	1
vagans Lea, 1906a	*Baris*	Tasmania. Cotype	1
variabilis Lea, 1908c	*Peripagus*	Queensland. Cotype Cairns	2
varians Lea, 1910e	*Ficicus*	N.S.W. Cotype Sydney: Lea	1
varipes Lea, 1908c	*Elleschus*	N.S.W. Cotype	1
vicina Lea, 1906a	*Misophrice*	Tasmania. Cotype	1
viridis Lea, 1910e	*Merimnetes*	Mt Kosciusko. Cotype	1
viridisquama Lea, 1911d	*Eniopea*	N.S.W. Cotype	1
wellingtoniensis Lea, 1908b	*Elleschus*	Summit of Mt Wellington, Tas.: Lea	1
xanthorrhoeae Lea, 1911c	*Timareta*	W. Australia. Cotype	1

ziczac Lea, 1909	*Epamaebus*	Tasmania. Cotype	1
ELATERIDAE			
electus Neboiss, 1957	*Hapatesus*	Sydney, N.S.W. *Hapatesus* 8185 Genitalia Slide E - 198 A. Neboiss 1956 Paratype *Hapatesus* *electus* n.sp. A. Neboiss 1956	1
LUCANIDAE			
laticollis Lea, 1910a	*Lissotes*	Cotype. Zeehan	1
parvus Lea, 1910a	*Lissotes*	Cotype. Hobart, Tas.: Lea 1283	1
punctatus Lea, 1910a	*Lissotes*	Cotype. Waratah, Tas.: Lea Waratah, Tas.: Lea	2
rodwayi Lea, 1910a	*Lissotes*	Cotype. Fig 54	1
rudis Lea, 1910a	*Lissotes*	Cotype. Burnie, Tas.: Lea Frankford, Tas.: Lea	2
LAMPYRIDAE			
olivieri Lea, 1915	*Atyphella*	Queensland. Cotype Cairns	2
LIMULODIDAE			
occidentalis Lea, 1907a	*Rodwayia*	W. Australia Blind Cotype	1
orientalis Lea, 1907a	*Rodwayia*	Tasmania Blind Cotype	2
LYCIDAE			
kershawi Lea, 1908a	*Trichalus*	King I., Tas. J.A. Kershaw	1
MELANDRYIDAE			
minuta Lea, 1908a	*Orchesia*	Cotype Hobart, Tas.: Lea	2
MELYRIDAE			
insularis Lea, 1908a	*Hypattalus*	King Island. Cotype	1
OEDEMERIDAE			
litoralis Lea, 1908a	*Copidita*	King Island. Cotype	2
PSELAPHIDAE			
auricomis Lea, 1911a	*Tyromorphus*	Tasmania. Cotype Mt Wellington, Tas.: Lea	3
bryophila Lea, 1911a	*Rybaxis*	Tasmania. Cotype Mt Wellington, Tas.: Lea	2
bryophilus Lea, 1910c	*Euplectops*	Tasmania. Cotype Waratah, Tas.: Lea Hobart, Tas.: Lea	2
castor Lea, 1911a	*Euplectops*	Tasmania. Cotype Stanley, in tussocks top of Nut	2
conicicornis Lea, 1911a	*Euplectops*	Tasmania. Cotype Hobart, Tas.: Lea	2
cylindricornis Lea, 1910c	*Articerus*	Victoria. Cotype Sea Lake: Goudie	2
elegans Lea, 1911a	*Palimbolus*	Tasmania. Cotype Mt Wellington, Tas.: Lea	1
flavoapicalis Lea, 1910c	*Eupines*	N.S.W. Cotype Sydney, N.W. Cox	2

foveiventris Lea, 1911a	*Pselaphus*	Tasmania. Cotype Mt Wellington, Tas.: Lea	2
frater Lea, 1911a	*Palimbolus*	Tasmania. Cotype New Norfolk, Tas.: Lea In tussocks	1
fuscicornis Raffray, 1900	*Eupines*	N.S.W. Cotype	2
hirsuta Lea, 1911a	*Rybaxis*	Tasmania. Cotype Mt Wellington, Tas.: Lea	2
indistincta Lea, 1911a	*Eupines*	Tasmania. Cotype Launceston, Tas.: Lea In tussocks	1
kingi Lea, 1911a	*Rytus*	N.S.W. Cotype National Park: Lea	1
litoralis Lea, 1911a	*Eupines*	N.S.W. Cotype	2
mira Lea, 1912a	*Daveyia*	Victoria. Cotype Portland: V.H.W. Davey	1
mira Lea, 1911a	*Eupines*	W. Australia. Cotype Swan R.: Lea	2
modica Lea, 1911a	*Eupines*	N.S.W. Cotype Forest Reefs, N.S.W.: Lea	1
parvidens Lea, 1911a	*Rybaxis*	Tasmania. Cotype Mt Wellington, Tas.: Lea	2
quadridentatus Lea, 1911a	*Tyromorphus*	Tasmania. Cotype Launceston, Tas.: Lea	1
quadrituberculata Lea, 1911a	*Rybaxis*	Tasmania. Cotype Marrawah, Tas.: Lea	2
quintana Lea, 1911a	*Eupines*	Tasmania. Cotype Launceston, Tas.: Lea Hobart, Tas.: Lea	2
rivularis Lea, 1910c	*Ctenisophus*	W. Australia. Cotype	2
sanguinipennis Lea, 1912c	*Rybaxis*	Tasmania. Cotype Latrobe, Tasmania, flood	1
tarsalis Lea, 1911a	*Eupines*	Tasmania. Cotype Mt Wellington, Tas.: Lea	1
tuberculiventris Lea, 1911a	*Pselaphus*	Tasmania. Cotype Mt Wellington, Tas.: Lea	1
variabilis Lea, 1911a	*Rybaxis*	Tasmania. Cotype Hobart, Tas.: Lea Mt Wellington, Tas.: Lea	4
villosus Lea, 1911a	*Pselaphus*	Tasmania. Cotype Launceston, Tas.: Lea	1
PTINIDAE			
cupreoniger Lea, 1912a	*Ptinus*	Tasmania. Cotype Stanley, in tussocks top of Nut	2
SALPINGIDAE			
variipennis Lea, 1908a	*Notosalpingus*	Cotype. Hobart, Tas.: Lea 1933	1
SCARABAEIDAE			
pseudotasmaniae Given, 1950	*Aphodius*	emerged 23.1.39 Glenelg Gretna, Tasmania 132 J.W. Evans: Paratype ♂ :	2
		Kingston, Tas., 2.48 J.R. Cunningham: Paratype ♂ :	1
		Kingston, Tas., 2.48 J.R. Cunningham: Paratype ♂ , ♀	2

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SCYDMAENIDAE			
colobopsis Lea, 1910c	*Scydmaenus*	Tasmania. Nests of *Colobopsis gasseri* Cotype. Swansea, Tas.: Lea	2
constricta Lea, 1910c	*Scydmaenus*	Tasmania. Cotype Hobart, Tas.: Lea	2
ectatommae Lea, 1910c	*Scydmaenus*	Tasmania. Nests of *Ectatomma metallicum* Cotype. Hobart, Tas.: Lea	1
latipennis Lea, 1910c	*Phagonophana*	W. Australia. Cotype	2
STAPHYLINIDAE			
infuscaticornis Lea, 1910c	*Polyobius*	N.S.W. Cotype	2
latebricola Lea, 1910c	*Termophila*	N.S.W. Cotype	4
nitida Lea, 1910c	*Dabra*	Victoria. Cotype Sea Lake: Goudie	2
pubescens Lea, 1910c	*Dabrosoma*	Tasmania. Cotype Hobart, Tas.: Lea	3
semiopacus Lea, 1910c	*Polylobus*	Tasmania. Cotype	2
tasmaniensis Lea, 1910c	*Polylobus*	Cotype Launceston, Tas.: Lea	2

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IMPACT OF TRAMPLING ON BOLSTER HEATH COMMUNITIES OF MT FIELD NATIONAL PARK, TASMANIA

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(with four tables, one text-figure and three plates)

ABSTRACT

GIBSON, N., 1984 (31 viii): Impact of trampling on bolster heath communities of Mt Field National Park, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 118: 47-52, pls 1-3. ISSN 0080-4703. Department of Geography, University of Tasmania, Hobart, Tasmania, Australia.

The impact of trampling on the alpine bolster heath communities of Newdegate Pass and the Mt Field West plateau (1300-1400 m) were investigated. It was found that in the track vegetation, percentage bare ground was significantly higher, and percentage cover of some taxa and species diversity were significantly lower than in the surrounding undisturbed vegetation. Degradation was measurably worse on sections of the track subject to water-logging. Implications of these findings for recreational management are discussed.

INTRODUCTION

As leisure time increases and society becomes more urbanized the usage of national parks will increase. Natural vegetation varies in its ability to sustain use without degradation (Liddle 1975a, b). Alpine vegetation is particularly susceptible to damage caused by walking along tracks due to its slow growth rate and short growing season (Willard & Marr 1970a, Billings 1973, Liddle 1975b).

Calais (1981) studied the impact of walking tracks on the vegetation of the Cradle Mountain-Lake St Clair National Park. He found significant damage occurred to alpine heath communities with as few as 500 passages/year. This threshold was defined as that amount of trampling which reduces the vegetation cover sufficiently to expose soil to erosion without precluding recovery. Further use above this level results in erosion of the soil layer to pavement, from which recovery is exceedingly slow.

The present study looks at the impact of trampling on the bolster heath communities at Newdegate Pass (1300 m) and the Mt Field West plateau (1400 m) (42°41'S, 146°30'E). Visitor usage data are not available but vegetation damage from trampling is apparent.

The bolster heath of both sites occurs intermixed with areas of coniferous heath and lichen covered dolerite boulders. The major bolster species are *Abrotanella forsteroides*, *Donatia novae-zelandiae*, *Dracophyllum minimum* and *Pterygopappus lawrencii* which can occur alone or in complex mosaics. These species are highly branched chaemaephytes with extremely short internodes. They can easily support the weight of a man. Single bolsters may be up to 2.5 m in diameter and almost 1 m tall.

Both areas are flat or gently sloping, with an acid peat soil of about 0.5 m developed over Jurassic dolerite country rock. No direct climatic data are available but records from the nearest meterological station indicate an annual rainfall of about 1500 mm with a winter maximum, and mean annual maximum temperature of about 10°C and mean annual minimum temperature of about 0°C. Snowfalls can occur at any time of the year, and the soil profile can freeze to depths of 0.5 m in winter.

Species nomenclature follows Curtis (1963, 1967), Curtis & Morris (1975) and Costin *et al.* (1979) except where otherwise indicated. Structural terminology follows Kirkpatrick (1983). The term bolster rather than cushion plant has been used to denote the hard compact nature of these species compared with the much softer northern hemisphere cushion species.

Impact of Trampling on Bolster Heath Communities

METHODS

To assess trampling damage three paired transects were established at Newdegate Pass (NP1-NP3) and two paired transects on the Field West plateau (FW1-FW2). The paired transects consisted of a set of 20 contiguous 25 cm square quadrats laid down the centre line of the track with another set parallel to this but 2 m into apparently undisturbed vegetation. A further transect was run at right angles to the track and a levelled profile constructed.

With each quadrat species occurrence was recorded and percentage overlapping cover was estimated using 25 equal subdivisions. Where a cover value of less than 5% was recorded in the field a value of 2% was assumed for the purpose of analysis.

The data were analysed using the nonparametric 2-tailed Mann-Whitney U test to test for significant differences between percentage cover of species in the track and undisturbed vegetation for the combined data set from five paired transects (Siegel 1956).

The diversity index $N_2 = [(\Sigma x)^2]/\Sigma x^2$ of Hill (1973) was calculated for each paired transect, where x = percentage cover of each species which occurs. A similarity index was also calculated: C = a/c, where a = number of shared species, and c = total number of species.

RESULTS AND DISCUSSION

The communities at each transect are described in table 1. Species for which significant differences ($P < 0.01$) in mean cover values were found from the combined data set are shown in table 2. Differences in mean percentage bare ground are detailed in table 3. Species number in each transect pair, and diversity and similarity indexes, are shown in table 4.

The effect of walking on these bolsters is to wear a distinct track generally about 25 cm wide (plates 1 & 2, fig. 1). In all cases percentage bare ground is significantly higher in the track vegetation although the magnitude of this difference varies (table 3). Areas subject to continuous seepage such as NP3 and FW1 have the highest percentages of bare ground in the trampled areas. Indeed percentage bare ground appears to give an excellent index of the saturation of the bolster peats at any point of the track on areas of low slope (cf. Willard & Marr 1970a).

TABLE 1

TRANSECT VEGETATION
Description of plant communities and soil moisture.

Newdegate Pass Transect 1 (NP1):	*Microcachrys-Donatia-Oreobolus pumilio-Dracophyllum* bolster heath on a gentle slope rarely subject to waterlogging.
Newdegate Pass Transect 2 (NP2):	*Donatia-Dracophyllum-Pterygopappus-Empodisma* bolster heath on a gentle slope rarely subject to waterlogging.
Newdegate Pass Transect 3 (NP3):	*Empodisma-Dracophyllum-Donatia* bolster heath on flat subject to continuous seepage.
Field West Transect 1 (FW1):	*Donatia-Dracophyllum-Empodisma-Celmisia saxifraga* bolster heath on flat subject to periodical waterlogging.
Field West Transect 2 (FW2):	*Dracophyllum* bolster heath on slight slope, rarely subject to waterlogging.

Plate 1 - Track through *Microcachrys* bolster heath at Newdegate Pass Transect 1.

Plate 2 - Damage of track through waterlogged bolster heath at Newdegate Pass.

Plate 3 - Damage to bolster wall of tarn at Newdegate Pass resulting from track.

TABLE 2

PLANT TAXA
Combined list of taxa showing those for which a significant difference between track and undisturbed vegetation exists.

*Empodisma minus****
*Celmisia saxifraga****
Lichen spp.***
*Pterygopappus lawrencii****
*Erigeron stellatus****
*Epacris serpyllifolia****
*Cyathodes dealbata****
*Gentianella diemensis****
Rhacomitrium spp.***
*Celmisia longifolia****
Moss spp.**
*Danthonia pauciflora***
Carpha spp.**
*Oreobolus pumilio**
*Dislaspis cordifolia**
Donatia novae-zelandiae
Dracophyllum minimum
Michrocachrys tetragona
Drosera arcturi
Carpha alpina
Garmedia fitzgeraldii F. Muell. & Rodway
Sprengelia incarnata
Mitrasacme archeri
Actinotus suffocata
Pentachondra pumila
Oreobolus acutifolius
Astelia alpina
Drimys lanceolata
Unidentified grass spp.

* $P \leq 0.01$ ** $P \leq 0.001$ *** $P \leq 0.0001$

Except for NP3 and FW1 transects, bare ground resulted from the death of bolster species on the track and not from disruption of the soil profile. In NP3 and to a lesser extent FW1 the soil profile has become churned by boot traffic especially at times of saturation of the soil profile.

No species had a higher mean cover in the track vegetation. Those significantly lower are listed in table 2. The taxa that were most noticeably reduced were *Empodisma minus*, *Celmisia saxifraga*, lichen spp., *Microcachrys tetragona* (highly significant in NP1 but not reflected in the combined data). Other species which were also highly susceptible are *Pterygopappus lawrencii*, *Erigeron stellatus*, *Epacris serpyllifolia*, *Cyathodes dealbata*, *Gentianella diemensis*, *Rhacomitrium* spp. and *Celmisia longifolia*. Some of these species had low cover values. The harder bolster species *Donatia novae-zelandiae* and *Dracophyllum minimum* are generally more resistant. These results are in strong agreement with those of Calais (1981) and generally support the assertion of Liddle (1975) that plants with basal apices and meristems tolerate trampling better than those which do not have such structure.

The lesser number of species on the tracks is generally a reduction rather than substitution of different species in the track vegetation (table 4). This is further indicated by the high values of the similarity index (table 4). The lower value for NP3 reflects the drastic reduction in number of species in the track vegetation. Similar reduction of species on tracks has been documented elsewhere (Hoffman & Alliende 1982).

TABLE 3

PERCENTAGE BARE GROUND

	NP1		NP2		NP3		FW1		FW2	
	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
Undisturbed vegetation	0.60	1.96	0.00	0.00	0.80	1.69	0.00	0.00	3.72	3.40
Track vegetation	8.92	8.64	23.40	16.52	82.40	12.88	45.40	16.24	26.00	19.00

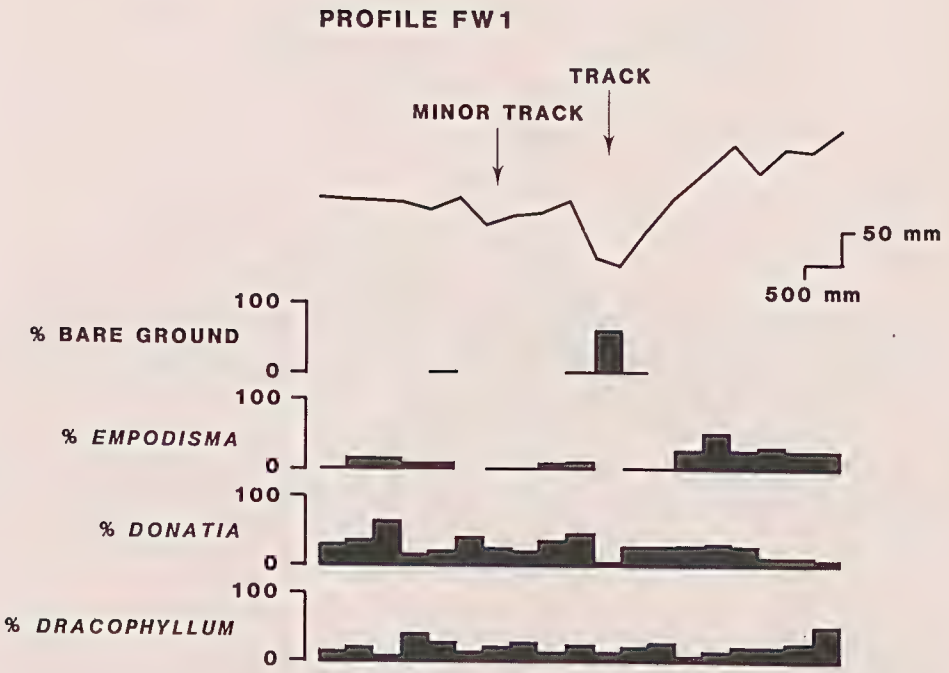

FIG. 1 - Profile transect of Field West transect 1 (FW1) showing percentage bare ground and percentage cover of dominant taxa, *Empodisma minus*, *Donatia novae-zelandiae* and *Dracophyllum minimum*.

The diversity index (table 4) shows a wide spread for these bolster heath communities reflecting their large degree of heterogeneity. In every transect however the diversity index of the track vegetation was lower than that of the undisturbed vegetation. Others have reported a variable response of diversity to trampling, depending on such factors as intensity of wear and condition of untrampled controls (Liddle 1975a).

CONCLUSIONS

This study has shown that damage to bolster heath communities, resulting from walking tracks, is variable. Sites with high soil moisture show the greatest damage. Indeed these sites, even with present relatively low usage, are at a critical stage because the soil profile, generally of a somewhat structured peat, is breaking down and eroding (Liddle 1975a, Willard & Marr 1970a, Calais 1981). It has been reported by others that once soil disturbance has occurred re-establishment is very difficult and slow (Billings 1973), perhaps of the order of hundreds of years (Willard & Marr 1970b).

On the low slope areas of Newdegate Pass and the Mt Field West plateau trampling on most sections of the track has not destroyed more than 50% of vegetative cover nor broken down the soil profile. Thus present usage is at or below the carrying capacity of this area, where carrying capacity is defined as the annual net primary production being equal to or greater than the annual amount of plant material destroyed by trampling. This is not the case on the wetter sections of the track where moderate levels of damage are apparent and tracks are beginning to spread laterally.

TABLE 4

NUMBER OF SPECIES, DIVERSITY INDEX (N_2) AND SIMILARITY INDEX (C). Definitions of N_2 and C are given in the text.

		NP1	NP2	NP3	FW1	FW2
Number of species	Undisturbed vegetation	21	21	23	16	12
	Track vegetation	17	17	8	16	8
N_2	Undisturbed vegetation	5.76	6.31	7.26	7.41	1.42
	Track vegetation	4.96	3.71	3.70	4.01	1.13
C		0.73	0.81	0.35	0.78	0.75

The data argue for the re-routing of tracks around persistent wet areas or installation of raised boardwalks. These measures would also protect associated geomorphological/biogeomorphological features, notably the small and fragile tarns dammed back by the bolster plants (plate 3).

ACKNOWLEDGEMENTS

I would like to thank the National Parks and Wildlife Service for permission to work in the park, Dr J.B. Kirkpatrick for comments on an earlier draft, Dr G. van de Geer for drafting the figure and Terese Hughes for typing the manuscript.

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A MIDDEN EXCAVATION — ROYAL TASMANIAN BOTANICAL GARDENS, HOBART

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(with three tables, five text-figures and one plate)

ABSTRACT

KERRISON, A.R. and BINNS, M.A., 1984 (31 viii): A midden excavation - Royal Tasmanian Botanical Gardens, Hobart. *Pap. Proc. R. Soc. Tasm.*, 118: 53-64, pl. 1. ISSN 0080-4703. Centre for Education, University of Tasmania, Hobart, Tasmania, Australia.

Radiocarbon analysis of charcoal taken from the base of a midden located within the Royal Tasmanian Botanical Gardens, Hobart, indicates that first occupancy of this site occurred some 5 000 years ago. The mussel *Mytilus edulis planulatus* provided the bulk of the shellfish diet which may have been supplemented with a number of small species including the gastropods *Bembicium auratum* and *Austrocochlea constricta zebra*. A feature of this site is the relatively rich supply of petrologically diverse stone artefacts. This is at variance with the general pattern for middens previously excavated in the Derwent River estuary. Also present are small, round, hard pebbles, a feature not previously reported from similar sites on the Derwent River. Scanning electron microscopic analysis of charcoal indicates that the she oak *Casuarina stricta* provided some of the wood fuel for fires at this site.

INTRODUCTION

Surface scatter of shell and charcoal in the northern corner of the Royal Tasmanian Botanical Gardens, herein "the Gardens", plus an exposed section in a nearby road cutting, indicated the possibility of finding a relatively intact aboriginal midden inside the Gardens' boundaries. Site development of such a midden would enhance the educational and informational roles played by the Gardens. An excavation was made to ascertain the degree of disturbance of the midden and generally to test the feasibility of open site development. This report details findings obtained from this initial excavation.

LOCATION

The Gardens are located in the Queens Domain, which is a public parkland situated on the west bank of the Derwent River some 2 km from the central business district of Hobart (fig. 1). There are numerous middens in and around the Gardens. Evidence of shell and ash, consistent with aboriginal middens, is readily discernible in the general area.

PERSPECTIVE

Possibly the earliest published reference to these middens was made by Gunn (1846) who drew attention to

> "... the immense quantity of comminuted shells, mixed in the soil of certain portions of Government Gardens, at Hobart Town ..."

Archaeological studies and excavations undertaken within the Derwent estuary have been summarized by Stockton & Wallace (1979). Some seven studies of various kinds had been reported by that date. Since then reports have been made by Lister (1979), Officer (1980), and Gaffney & Stockton (1980). Officer (1980) located, mapped, and briefly described the middens, quarry sites and rock shelters along the shores of the estuarine Derwent from New Norfolk to a line connecting Blinking Billy Point to Tryworks Point (fig. 2). In all, he recorded 416 shell middens (118 on the west bank of the Derwent and 298 on the east), and eleven quarry or tool manufacturing sites.

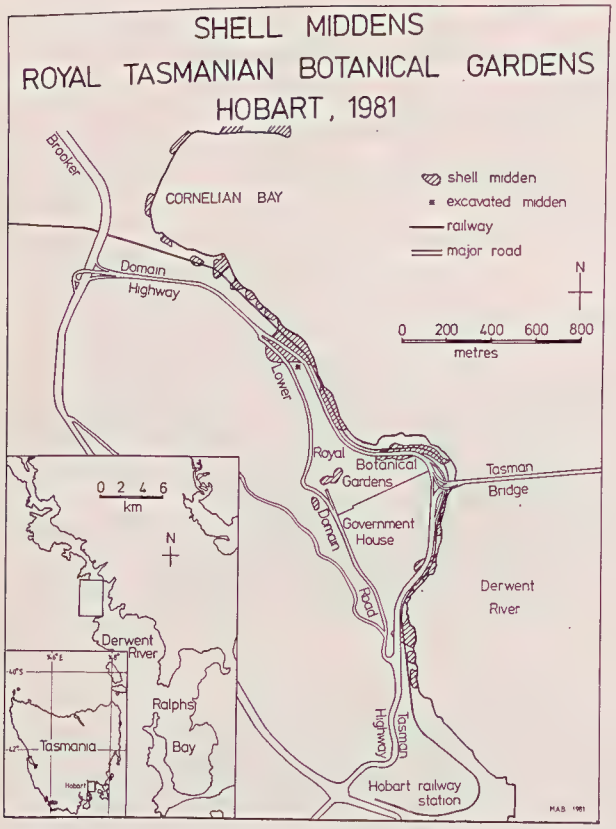

FIG. 1 - Map showing the location of middens in and around the Royal Tasmanian Botanical Gardens.

European settlement in the general area has undoubtedly destroyed, or buried, numerous middens and aboriginal quarries and thus the true density of such sites would certainly be higher than shown.

EXCAVATION METHOD

Excavation of the Gardens midden commenced during August, 1980. A pit was opened up close to a footpath and a highway cutting. This site was abandoned as it soon became obvious that severe dislocation of the midden material had occurred, presumably during the road and footpath construction.

A second excavation was then undertaken on a mound some 30 metres south of the first site. This pit was one metre square and spit depths were 50 mm. All material was sieved using a 6 mm mesh. All cultural material was collected including all shell which had been retained by the sieve.

The top spit contained such foreign matter as railway clinker, ring tops from drink cans and cigarette butts. It appeared from Spit 2 onwards that in this location the midden was stratified and had not suffered dislocation. However, during laboratory analysis of sieved material two pieces of bone from Spit 5 were identified as belonging to the rabbit or hare (Dr P. Murray, pers. comm.) which means that some recent contamination of the midden, at depth, has occurred. The western section of the pit (fig. 4) exhibits a feature resembling an infilled rabbit burrow. No other features indicating contamination or disturbance were noted during the excavation.

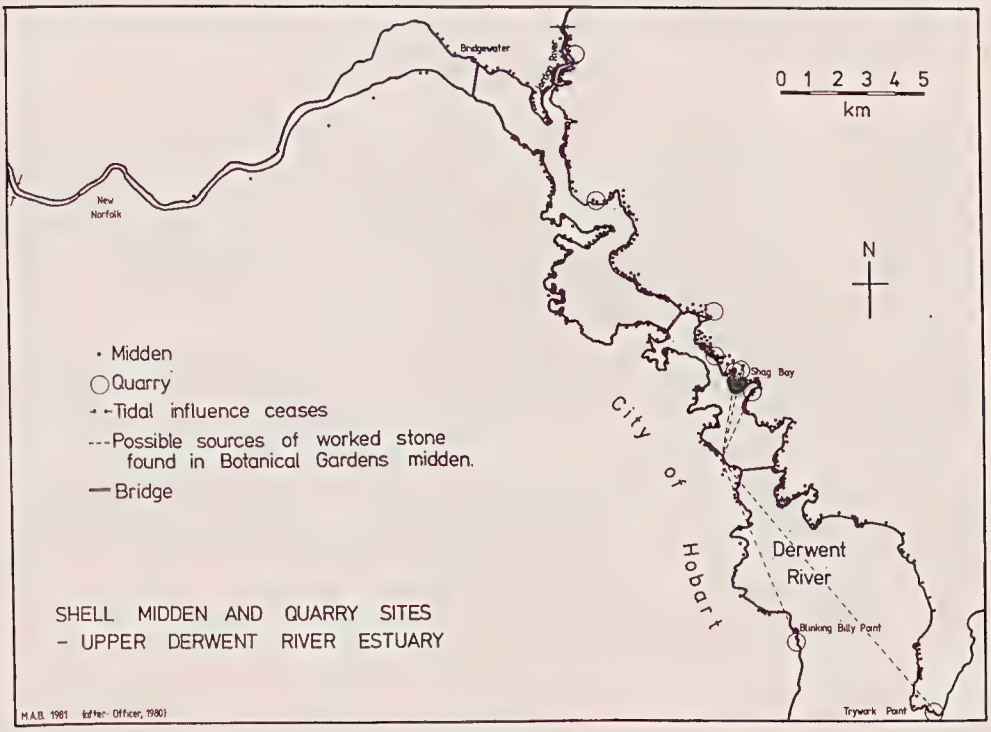

FIG. 2 - Map showing the location of middens and quarries in the middle and upper Derwent River Estuary.

Charcoal in Spits 1, 2 and 3 was in a powder form and not retained by the sieve but was collected regularly from Spit 4 onwards.

From Spit 6 (that is, from a depth of 0.3 m) normal, on-site sieving had to be abandoned due to the changed nature of the midden matrix. The midden material had been bonded by clay. Decomposing dolerite, the country rock in this area, is presumably the source of the clay.

All material from Spits 6 to 11 was bagged and transferred to a laboratory for analysis. Considering the large volume of material that had now to be treated elsewhere it was also decided to excavate only half the pit from Spit 9 onwards. Thus Spits 9, 10, 11 were $1 \times 0.5 \times 0.05 m^3$ in volume. Spit 11 reached a sterile base and excavation was terminated.

The material from Spits 6 to 11 was treated as follows. Each bag was opened into the 6 mm sieve. The contents were washed to remove the clay and the sieve residue was then dried and re-bagged. The material from all spit levels, that is all the material retained by the sieve, was then analysed using the following procedure.

1. The total mass of all shell for each spit was found and the percentage mass for each species component was calculated. The number of shells in each species component was also counted when it was possible to do so. For mussel, which is generally in a crushed state throughout the midden, the umbos were counted and divided by 2, but for oyster the only reasonable comparison between spits was to compare mass.

2. The stone flakes were separated and labelled according to spit level as were the pebbles found throughout the midden.
3. All ochre was collected.
4. Charcoal samples from Spit 4 onwards were collected on site, where possible, or from the washed residue.

SHELL

The mussel *Mytilus edulis planulatus* is dominant throughout the midden. The percentage mass ranges from 96.9% in Spit 1 to 99.5% in Spit 11 (fig. 3). By contrast the mud oyster *Ostrea angasi* is much less important as a food source at this site. The considerable shell bulk of *Ostrea* gives a percentage mass value which, if equated with food value, is obviously inflated. The shell weight of one medium-sized mud oyster with a dorso-ventral length of 80 mm is approximately 70 grams. By contrast, the shell of a good-sized mussel of near 70 mm weighs approximately 15 grams. Thus, when percentage mass of shell for different species is compared (fig. 3) it must be remembered that one or two fragments of *Ostrea* shell may constitute a whole percentage point.

From midden sites further up the Derwent estuary the mussel *Xenostrobus securis* has been recorded (Gaffney & Stockton 1980). It appears that *X. securis* occurs in localities where permanent supplies of fresh water are found entering the system. Indications are that the *Xenostrobus*:*Mytilus* ratio at a site may be a valuable environmental indicator since any change in the supply of fresh water results in a consequent change in the *Xenostrobus*:*Mytilus* ratio. *Xenostrobus securis* was not recorded in the Gardens midden. At the present time there are no permanent supplies of fresh water entering the Derwent in the immediate vicinity of the midden. The complete absence of *X. securis* indicates that this situation prevailed during the period of Aboriginal occupation of the site.

An alternative hypothesis is that *Mytilus* was a preferred food source over *Xenostrobus*. This appears unlikely given that the morphological differences between the two species are very slight, making selective collecting extremely difficult.

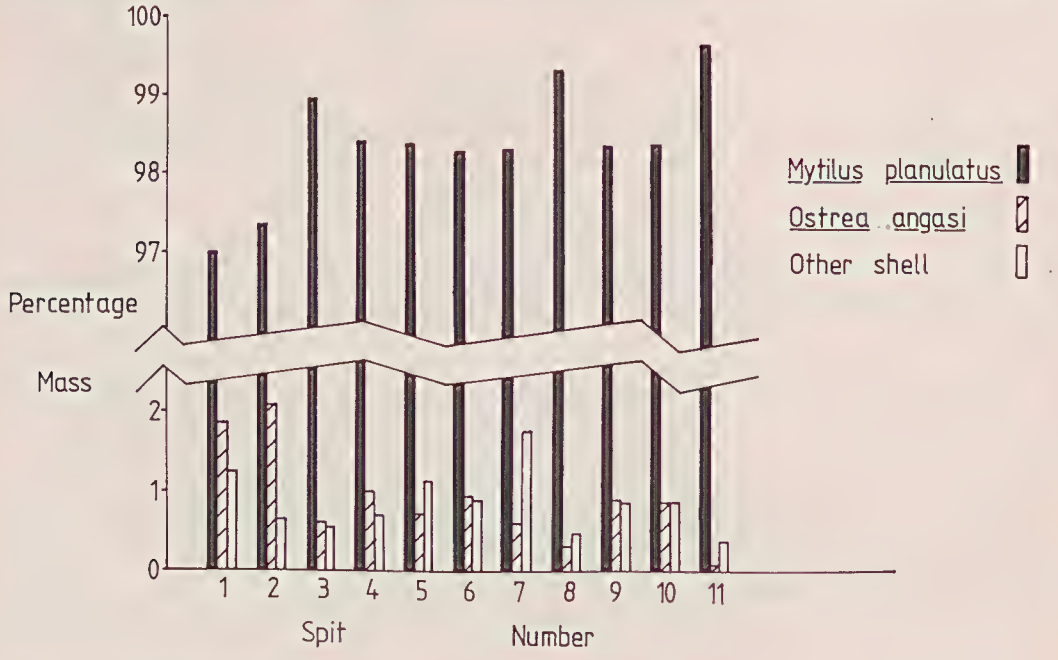

FIG. 3 - Percentage mass of component shell for each spit level.

Apart from *Mytilus* and *Ostrea* the remaining shell, classified as "Other Shell" in fig. 3, makes up one or two percent of the shell mass for any one spit level. Of this "Other Shell" the small coiled gastropods *Bembicium auratum* and *Austrocochlea constricta zebra* are the most numerous and persistent, being present in each spit level. The apex-base length of these shells rarely exceeds 12 mm. The small pelecypods *Venerupis crenata* and *V. diemenensis* may have been exploited for food, although the dorso-ventral height, for both species, rarely exceeds 20 mm.

The significance of these small shells in the midden is conjectural. It is not clear whether the gastropods and pelecypods mentioned above contributed to the food supply or were incidental to the gathering of mussel. It is possible that they were collected along with the mussel but perhaps not deliberately, but once collected became part of the food supply. There is evidence from work done elsewhere in Tasmania (Vanderwal 1978) that, on occasions, numerous species were collected for food and the size of the shell seems not to be an altogether important factor. Indeed, many of the *Mytilus* specimens from the Gardens midden are very small, overall dorso-ventral length quite often being as low as 25 mm.

The land snail *Caryodes dufresnii* is present throughout the midden but, as shown in table 1, it becomes more prominent towards the top of the midden. The shell of this snail is quite fragile yet is usually found complete. This is in direct contrast to the crushed and burnt nature of the mussel shell. It seems that *Caryodes* invaded the midden during those periods when the midden site was unused.

Attempts to use the minor shells as environmental indicators were unsuccessful. This was primarily due to the lack of conclusive information on their environmental significance in the Derwent River. Another aspect of this problem is the possibility of selective rather than incidental collection of minor shells.

TABLE 1

COMPONENT SHELL NUMBERS FOR EACH SPIT LEVEL

Spit level	1	2	3	4	5	6	7	8	9*	10*	11*
Mytilus edulis planulatus	200	253	552	344	221	280	163	140	48	45	108
Ostrea angasi				Fragments		all		levels			
Bembicium auratum	78	24	48	22	25	27	37	28	8	9	5
Austrocochlea constricta zebra	35	25	41	29	29	15	16	6	2	7	4
Notoacmea alta	3	3	5	3	2	5	1	2	-	1	2
Venerupis crenata	3	1	-	4	1	-	1	4	-	-	-
Venerupis diemenensis	-	2	1	-	11	5	9	8	2	1	-
Lepsiella vinosa	-	1	1	3	2	1	1	1	-	1	-
Siphonaria diemenensis	-	-	1	-	-	-	-	-	-	-	-
Collisella mixta	-	-	-	-	-	-	2	-	-	-	-
Caryodes dufresnii	8	13	11	5	6	2	1	1	-	-	-
Tasmaphena ruga	-	-	1	-	-	-	-	-	-	-	-

* Spits 9, 10, 11 are half volume spits.

SHELL DISTRIBUTION AND MIDDEN PROFILE

The total depth of shell in this pit is 0.55 m. Distinct horizons of shell were encountered during excavation with the principle concentration occurring between 0.1 and 0.2 m. below the surface. This depth coincides with Spit levels 3 and 4 (see fig. 3 and table 1). At these levels an uninterrupted band of closely packed mussel was found. Relatively high concentrations of *Bembicium* and *Austrocochlea* also occur at this level. It was noted that in the northern corner of the pit the mussel shells were layered in such a manner that layers made a distinct angle with the horizontal (fig. 4).

Midden Excavation — Hobart

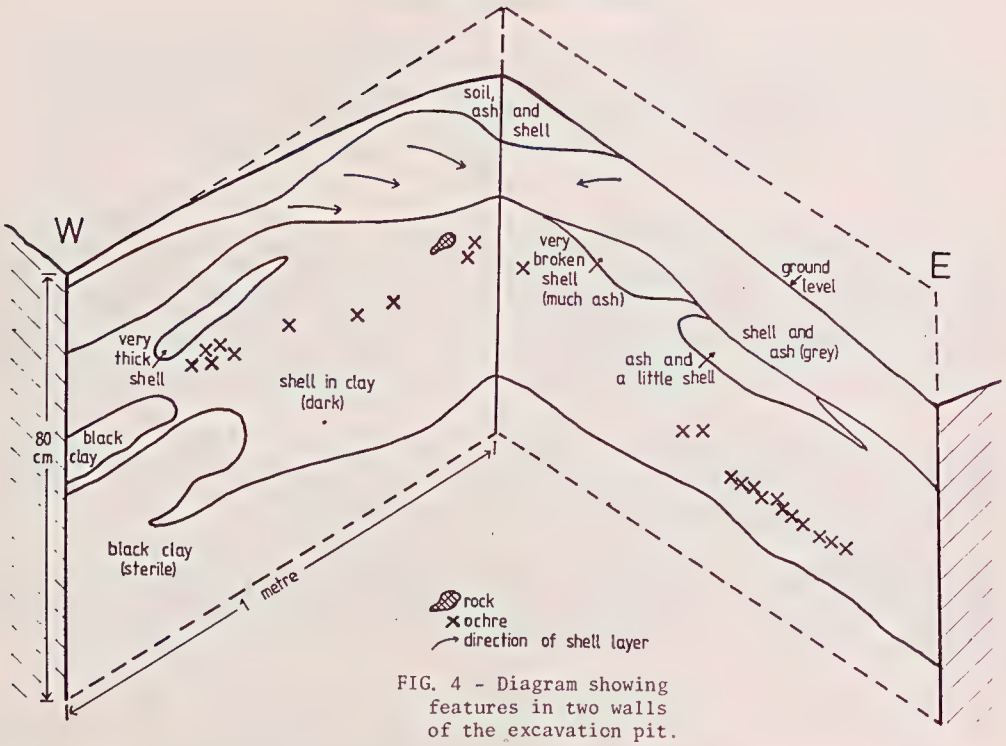

FIG. 4 - Diagram showing features in two walls of the excavation pit.

Beneath Spits 3 and 4 shell concentrations occur but only as pockets, as can be seen in fig. 4. The shell counts never reach the same high levels as occur in Spits 3 and 4. It is of interest to note that with depth there is an overall decrease in the number count of the minor shells. This seems to be a real rather than apparent change. The possible reasons could be selectivity in collection, environmental changes or shell fragility. However, fragility and consequent crushing would not seem to be a major factor because of the inherent structural strength of most of the minor shells, and the lack of discernible change, with depth, in the fragmentation of *Mytilus*.

STONE

Dolerite boulders of various sizes and a variety of hard, silica-rich stone flakes and pebbles were extracted from the midden.

The dolerite was in the form of assorted lumps, commonly of cobble size (64-256 mm), weathered and usually in a disintegrating state. The inclusion of this rock within the midden may, in part, be accounted for by local geology, the Queens Domain and areas surrounding the Gardens being primarily composed of dolerite. However, the rock was found at all levels within the midden, and not merely basal, implying at least some purposeful introduction.

The purpose for which the dolerite was used remains unclear. The texture and fracturing qualities of this rock are such that it is of little value in producing implements with fine edges. No juxtaposition patterns, or associations, for the rock were noted during the excavation. Evidence of charring, which could be expected if some of the rock had been used as hearth surrounds, was absent. This, in turn, could be explained by the very weathered nature of much of the dolerite which would obliterate evidence of charring.

PEBBLES

In the main the pebbles have an exotic petrology. They are typical of the pebble dropstones found in local Permian sediments and this is the most likely source. The pebbles may be found loose on rocky foreshore stretches of the Derwent such as occur in the Gardens area where they may be found today. The conclusion that the aborigines actually collected the pebbles from in front of the Gardens has to be tempered by the fact that middens are being undercut and slumping into the Derwent all along the waterfront in the Gardens area. The pebbles there today may actually be coming fron the eroding middens.

Table 3 shows a clustering of pebbles and flakes and the pebbles were probably used during the preparation and repair of the stone flakes. Many of the flakes in Spits 4 to 11, where the pebbles also occur, are small and fine (table 2). The pebbles may have been used as minute hammer stones or for delicate pressure application during flake and edge preparation.

FLAKES AND PEBBLES

Eighty-one pieces of very hard stone of various petrological types were also extracted. Of this number 21 pieces are hard pebbles and the remaining 60 pieces are flakes produced during the manufacture or repair of stone tools.

The 60 flakes were divided into two groups. Group One has 11 pieces which show clear evidence of some edge preparation or use wear. Figure 5(a) (b) (c) are examples from this group. The remaining 49 flakes constitute Group Two. These flakes show no edge preparation but clearly have been removed by force from cores of stone.

Table 2 gives information on dimensions and mass of Group One and Two flakes and the pebbles.

Table 3 shows the distribution of all flakes and pebbles through the midden. Petrological composition, derived from hand lens examination, is also shown and, where possible, source localities are given for the rock types. Petrological composition of both flakes and pebbles varies widely. The most common stone includes various quartz hornfels, chalcedonic rock and fine-grained basalts. Examination reveals that hornfels have been formed from a variety of sediments including well-sorted siltstones and sandstones, poorly-sorted sandstones, sandstones with clay, and siltstones with fossils (Permian). Local geology would indicate that original deposits were most likely of Tertiary, Triassic and some certainly of Permian age. Also present, and more exotic in nature, are two pieces of what appear to be fine-grained granite, a piece of sheared quartzite, pieces of devitrified volcanic glass and a piece of schistose quartzite.

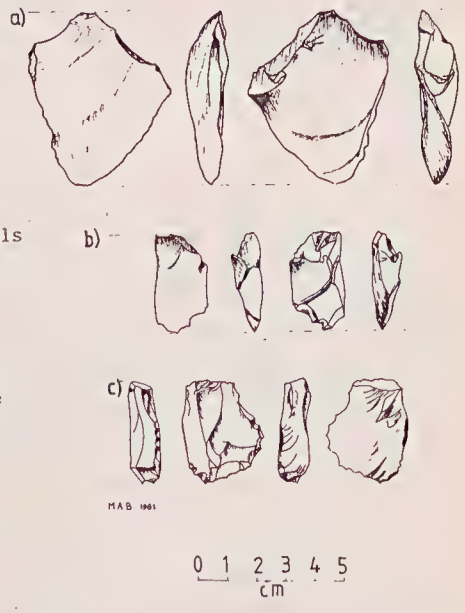

FIG. 5 - Examples of the stone tools extracted from the Gardens midden.

The chalcedonic rocks almost certainly come from the Sandy Bay volcanic complex which is some 7 km down river from the Gardens. Pinpointing the other rock sources is much more difficult. The geology of the Hobart area is such that there are numerous igneous-sedimentary contacts. Jurassic dolerite intruded Triassic and Permian sediment giving rise to a wide variety of hornfelsic rocks. Later, Tertiary sediments were baked in many places by Tertiary basalts. Thus, a variety of rock suitable for tool making is to be found in and around Hobart (Sutherland 1972). Locating the

exact sources of the hornfelsic rocks found in the Gardens midden would in most instances be extremely difficult. The quartzitic rocks and the granites are certainly not of local origin. However, it cannot be concluded that these and other exotic rocks were traded or carried into the Hobart area. Dropstones, or "erratics", of a diverse petrological nature occur in Permian sedimentary outcrops in and around Hobart. This factor complicates the study of trade or importation of stone into the area. Some of the more probable source localities for the midden stone are shown in fig. 2. Detailed information on these and other quarry sites within the Derwent, and in the State generally, was given by Sutherland (1972).

TABLE 2

FLAKES AND PEBBLES: LINEAR DIMENSIONS AND MASS

	Mean	Mode	Range
FLAKES			
Group I			
length	32	25	16-50
width	24	20	11-45
height	10	8	4-12
mass	8.1	3.4	1.1-26.5
Group 2			
length	23	15	10-40
width	16	12	8-40
height	7	5 & 9	0.2-16.1
PEBBLES			
length	21	18	10-40
width	15	13	7-36
height	9	5	4-19
mass	4.8	1.0	0.6-27.2

Dimensions in millimetres; mass in grams.

The diversity of stone type combined with the relative abundance of flakes were features not expected of this site. The number of flakes extracted from recorded excavations on the Derwent is given below:
Alum Cliffs (Stockton & Wallace 1979): 2 flakes.
Fishers Hill (Stockton & Wallace 1979) two pits: 0 and some (?) flakes.
Shag Bay Rock Shelter (Vanderwal 1977): 2 flakes,
Jordan River (Gaffney 1978): 7 flakes.
By contrast, the Gardens midden gave 60 flakes.

Petrological diversity is also unique to this midden. The only similar situation in this regards is to be found at the Risdon Cove Historic Site (Lister 1979) which is some 5 km upriver from the Gardens and on the opposite bank. However, this is not a midden and is described as a specialized stone tool site.

OCHRE

Pellets of ochre were recovered from all levels. Concentrations occurred in Spits 4 and 5 where 46 and 39 pieces respectively were collected. By contrast the next highest count occurred in Spit 2 (16 pieces) with counts never exceeding 10 pellets for any other spit. Concentrations of ochre can be seen in the walls of the excavation as is shown in fig. 4.

Most of the ochre is yellowish-brown in colour, gritty to the feel and most commonly of diameter 10 mm or less. Occasionally pieces of more reddish ochre were found. To the authors' knowledge no ochre quarry has been reported in this general area. This would account for the general lack of quality in the ochre which, in the main, appears to be a weathering product of local rocks.

CHARCOAL - RADIOCARBON DATE

Charcoal and charcoal powder darkens the entire midden. Collection commenced at Spit 4 higher charcoal being powdery or minute, and fine enough to pass through the sieve. Lighter patches of grey ash mark possible hearth locations (fig. 4). Radiocarbon dating analysis was undertaken on a 3 gm mass of charcoal extracted from base level material. Results obtained give a first occupancy date for the midden of 5 210 ± 110 years BP (Beta - 5099). This date is consistent with basal dates obtained within the Derwent estuary (Stockton & Wallace 1979). After a glacial low at around 20 000 years BP the climate became warmer resulting in rising sea levels. By 5-6 000 years BP the sea appears to have reached a level very near that of the present day. Marine shellfish colonized flooded

TABLE 3

PETROLOGICAL DISTRIBUTION OF FLAKES AND PEBBLES — BOTANICAL GARDENS MIDDEN

Rock Type	Source	F	P	Spit Level										
				1	2	3	4	5	6	7	8	9	10	11
Hornfels: grey, poorly-sorted clay sediments	A	8					2	2		1	1	1		1
Hornfels: light grey, medium sorting	A	5						1			2	2		
Hornfels: grey, fine-grained	A	5		1			1	3						
Contact metamorphosed Permian siltstone	A	5	1*				2		1+1*		2			
Basalt: fine-grained	A	5	1*				1*	1	1	1	2			
Hornfels: brown, fine-grained	A	2							1		1			
Hornfels: pink, poorly-sorted	A	2						1			1			
Hornfels: silver/grey, medium- to fine-grained	A	2								2				
Hornfels: grey, thinly-bedded, fine-grained	A	2		1		1								
Chalcedony	B	6							1		5			
Jasper/chalcedony	C	1	1*				1*						1	
Hornfels: pale yellow, fine-grained	C	2							1	1				
Silicified breccia	D	2							1		1			
Devitrified volcanic glass	E	6			1			4	1					
Schistose quartzite	E		2*										1*	1*
Granite: grey	E		2*				1*						1*	
Sheared quartzite	E		1*							1*				
Granite or arkose: brown, fine-grained	E		1*					1*						
Granite or aplite: white	E		1*							1*				
Silicified sandstone: red, poorly-sorted	F	1									1			
Quartz	F		3*				1*	1*	1*					
Hornfels	F		1*					1*						
Permian sandstone	A		6*				3*	1*		1*	1*			
Baked mudstone: brown/pink	F		1*							1*				
Flakes: unidentified assortment	F	6						1	1		2	1	1	

Source: A - exact location unknown, but petrology indicates Hobart area; B - Sandy Bay; C - probably Shag Bay; D - probably near Tryworks Point; E - unknown, but not Hobart area; F - unknown.

Note: Spits 9, 10, 11 - half volume spits. F = flakes. P = pebbles. * = pebbles.

valleys, such as the Derwent, and Aboriginals exploited this food source. Middens with older basal dates would have been closer to older, and thus lower, shorelines. Rising seas would have inundated and most likely destroyed such middens. Thus, basal dates for middens in the Derwent estuary reflect most recent high sea levels, given that Aboriginal occupancy of the continent occurred within the last 50 000 years. Within this time span sea levels have been lower than those of the present (Orchiston 1979).

Charcoal Micrographs

Charcoal samples from Spits 4, 6, 8 and 10 were subjected to electron probe micro-analysis using a scanning electron microscope (McGinnes, Harlow & Beall 1976). Micrographic sections revealing cellular structure were obtained. By comparing these with micrographs of known samples it was hoped to identify the species of tree from which the charcoal had been derived. Good micrographs were obtained for charcoal samples taken from Spits 6 and 10. The evidence suggests that at these levels wood from the she oak *Casuarina stricta* was used as a fuel for fires (plate 1). These trees are growing in the vicinity of the midden today.

It would seem that electron microprobe analysis of charcoal could be of benefit in archaeological investigations of aboriginal sites. With controlled charcoal sampling at each spit level, combined with electron microscopy, it may be possible to establish an overview of fuel collecting habits during the occupancy of a particular site.

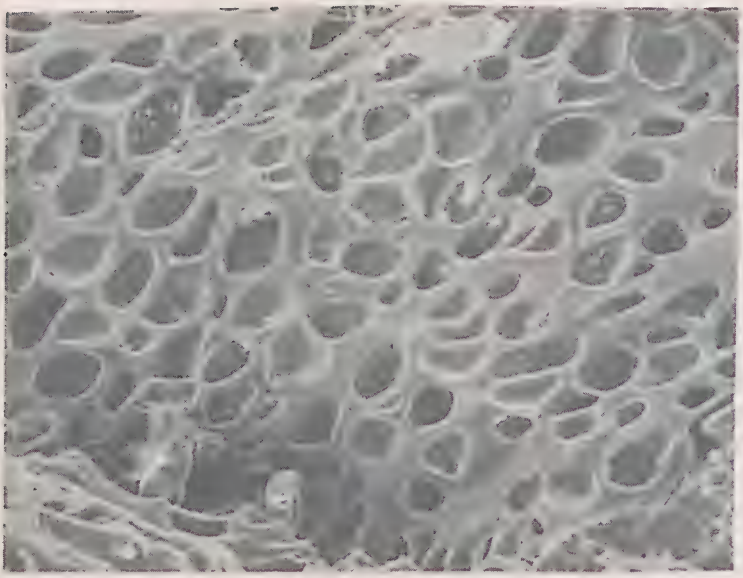

Plate 1 - Electron micrograph of a charcoal sample taken from Spit 6. Mag. ×300. The cellular structure as shown indicates that the sample is charcoal from the she oak *Casuarina stricta*.

BONE

The only bone to be positively identified as such and be retained by the sieve came from Spit 5. Two pieces of mammal bone have been identified as a patella, which has a maximum dimension of 8 mm, and the epiphysis of the tibia, maximum dimension 18 mm. The most likely source is the rabbit or hare (Dr P. Murray, pers. comm.) which means that some post-European contamination of the midden, at depth, has occurred.

SUMMARY AND DISCUSSION

Generalizing from the available archaeological evidence the features that Derwent River middens exhibit may be summarized as follows. The middens usually have:

(i) a depth of between 0.5 and 1.0 m,
(ii) shell content composed primarily of mussel, some oyster and a variety of smaller species,
(iii) a small number of stone artefacts,
(iv) a minimal or zero bone content,
(v) ochre present as small pellets,
(vi) assorted lumps of local rock,
(vii) charcoal, hearths and distinct layers of shell, and
(viii) basal dates of some 5 000 years BP.

In the Gardens midden only (iii) - the number of stone artefacts - has shown a marked deviation fron the general pattern.

Derwent River middens may be seen as examples of single resource utilization. The absence of bone supports this view. The scarcity of stone artefacts may be linked to the lack of need for stone tools when gathering and eating shellfish. In this sense the Gardens midden is atypical for here there is a comparatively high incidence of stone artefacts. A possible explanation for this situation may be linked to the general smallness of the flakes and the range of their petrology.

On the opposite shore of the Derwent the middens, with their low flake content, are in close proximity to quarries (fig. 2) or the specialized stone tool site (Lister 1979). Procurement of suitable stone would not require lengthy travel. There is also evidence to show that flakes were fully prepared at the quarry sites. For example, the paddocks sur-

rounding the quarry near Tryworks Point (fig. 2) are littered with chips of the quarried silicified breccia and rounded, cobble-sized hammer stones. Similarly at Oyster Cove, in the D'Entrecasteaux Channel south of Hobart, Winter (1976) counted millions of waste flakes associated with the quarried silcrete outcrop.

The Gardens midden is, by contrast, remote from the nearest known quarry. Suitable stone and flakes would need to be conserved with manufacture and repair being carried out at the midden. In these circumstances repair of flakes would be important, thus explaining the need for small pebble hammer stones and the consequent smaller flakes found in this midden. The lack of a nearby single source of rock would also account for the wide petrological diversity.

This interpretation may not be applicable to the whole midden. The pattern of occupancy postulated above does not fit well with the evidence from the topmost three spits where no pebbles and only four flakes were found (table 3).

If site development of the Royal Botanical Gardens midden takes place in the future the extended excavation would provide further information on the occupancy pattern. It would also help clarify the context and relationship of this midden to others in the Derwent area.

ACKNOWLEDGEMENTS

We wish to thank Dr M.R. Banks, University of Tasmania, and Dr D.C. Green, Mines Department, for their help in petrological identification; Mrs E. Turner, Tasmanian Museum and Art Gallery, for her help in shell identification and information on particular shell habitats; Mr D. Ransom, National Parks and Wildlife Service, for his help in some stone tool identification; Mr I. Bailey for his help in field and laboratory work; Mr A. Goede, University of Tasmania, for directing our attention to the possibilities in the use of electron micrographs of charcoal and for allowing us to compare our results with his collection of charcoal micrographs of Tasmanian flora; Dr P. Murray, formerly of the Tasmanian Museum and Art Gallery, for his identification of bone pieces; and to the Tasmanian Archaeological Society for financial assistance in relation to radiocarbon dating.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 118, 1984

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A YOUNG STRAP-TOOTHED WHALE IN TASMANIAN WATERS

by E.R. Guiler
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(with two tables)

ABSTRACT

GUILER, E.R., 1984 (31 viii): A young strap-toothed whale in Tasmanian waters. *Pap. Proc. R. Soc. Tasm.*, 118: 65-68. ISSN 0080-4703. 8 Tiersen Place, Sandy Bay, Tasmania, Australia.

The stranding of a young Strap-toothed Whale is the first breeding record of this species in Australia. The species is present in Australian waters in summer probably associated with calving and the early growth of young. Measurements are given of the skull of the young whale.

INTRODUCTION

The Strap-toothed whale *Mesoplodon layardii* (Gray, 1865), family Ziphiidae, has a circumpolar distribution being found in New Zealand (Gaskin 1972), South Africa (Gray 1865), Australia (Dixon 1980) and South America (Bruyns 1971). In spite of this wide distribution little is known of its biology, although specimens have been examined at more than 50 strandings, most of these being in New Zealand and Tasmania.

THE EVENT

On 20 January 1983 two whales were reported stranded in northeastern Tasmania. The whales were of different sizes and the larger animal had been dead for a few days and was rolling about in the surf at Little Musselroe Bay (lat. 40°45'S, long. 148°05'E). The second whale was smaller and stranded at nearby Lanoma Point (lat. 40°44'S, long. 147°58'E) and was in a more advanced state of decay than the other specimen. The skull of each whale was recovered by Mr P. Allbrook.

Both whales were *Mesoplodon layardii* (Gray). Some doubt exists about the sex of the Musselroe specimen which photographs show to have been large (about 6 m long), and clearly an adult. The original stranding report from N.P.W.S. Ranger Le Fevre stated that one of the residents in the area remembered seeing the animal's penis. The mesorostral groove was ossified for one-half of its length but doubt exists about the use of this feature in determining sex, Nishiwaki & Kamiya (1958) expressing reservations regarding its validity. McCann (1965) concluded that the ossification of the groove was an indication of age. However, the teeth of the whale were not of the elongated, blunt form of the male (Watson 1981) but were small, pointed and although each tooth had penetrated the side of each mandible to the extent of 2-3 mm it had not appeared above the surface of the gums. From this, I conclude that the specimen probably was female.

The smaller whale was estimated by Mr Allbrook to be about 2.5 m in length. The birth length of these whales is about 2.2 m (Watson 1981) and this size, combined with the characters of the skull identify the whale as a juvenile *M. layardii*. The teeth, although not erupted through the gums, were of the male form. The sutures of the skull were ossified with the exception of the premaxillary which was poorly ossified along its posterior and postero-lateral surfaces.

As this is the only skull reported from a juvenile of this species full measurements are given, using the criteria of Moore (1963) (table 1). Dimensions are also given of the adult skull since it is an unusually large specimen (Warneke 1963).

TABLE 1

THE SKULL MEASUREMENTS OF TWO *MESOPLODON LAYARDII* FROM TASMANIA.
Measurements (mm) and numbers follow the system of Moore (1963).

	Juvenile	Adult
1 Greatest length of skull	690	1090
2 Greatest length of rostrum from tip to line connecting apices of antorbital notches	410	730
3 Tip of rostrum to posterior margin of pterygoid nearest mid-sagittal plane	495	870
4 Tip of rostrum to posterior wing of pterygoid	530	880
5 Tip of rostrum to most anterior extension of pterygoid	330	650
6 Tip of rostrum to most posterior extension of maxillaries between the pterygoids	400	680
7 Tip of rostrum to most posterior extension of maxillary plate	610	990
8 Tip of rostrum to anterior margin of superior nares	470	835
9 Tip of rostrum to most anterior point on maxillary crest	480	840
10 Tip of rostrum to most posterior extension of temporal fossa	600	930
11 Tip of rostrum to most posterior extension of lateral tip of pre-maxillary crest	558	-
12 Tip of rostrum to most anterior extension of pterygoid sinus	490	700
13 Greatest length of temporal fossa	96	115
14 Greatest length of orbit	85	110
15 Greatest length of right nasal on vertex of skull	40	77
16 Length of nasal suture	25	40
17 Greatest breadth of skull across posterior orbital process of frontals	275	430
18 Greatest breadth of skull across zygomatic process of squamosals	285	405
19 Greatest breadth of skull across centres of orbits	280	428
20 Least breadth of skull across posterior margins of temporal fossae	215	260
21 Greatest lateral spread of occipital condyles	105	130
22 Greatest width of wider occipital condyle	45	55
23 Greatest length of longer occipital condyle	60	91
24 Greatest width of foramen magnum	45	46
25 Greatest lateral spread of exoccipital bones	250	-
26 Greatest lateral spread of nasal bones	48	58
27 Greatest distance between premaxillary crests	25	60
28 Greatest extension of right premaxilla posterior to right nasal	30	62
29 Greatest spread of premaxillary crests	90	156
30 Narrowest spread of smooth part of premaxillae beside nares	80	115
31 Greatest spread of premaxillae anterior to no.30	90	110
32 Greatest spread of premaxillae at middle of rostrum	50	50
33 Greatest width of rostrum at apices of antorbital notches	100	135
34 Greatest width of rostrum at apices of preminential notches	180	130
35 Greatest width of rostrum at midlength of rostrum	50	60
36 Greatest depth of rostrum at midlength of rostrum	52	68
37 Greatest transverse width of superior nares		50
38 Inside width of inferior nares at apices of pterygoid notch	85	70
40 Greatest width of temporal fossa perpendicular to long axis	55	69
41 Least distance between main or anterior maxillary foramina	95	130
42 Least distance between premaxillary foramina	23	34
43 Posteromesial margin of left maxillary foramen to apex of left antorbital tubercle	35	63
44 Greatest length of vomer on surface of palate	110	170
47 Centre of right orbit to nearest margin of superior nares	112	-
48 Centre of left orbit to nearest margin of superior nares	140	-
49 Apex of pterygoid notch to anterior edge of pterygoid sinus	60	-
50 Greatest width of pterygoid sinus perpendicular to long axis	20	-

DISCUSSION

The occurrence of a juvenile *M. layardii* constitutes the first breeding record for this species in Australian waters. Although not an uncommon species, some 28 individual strandings have been recorded from Australia by Dixon (1980) and 19 from New Zealand (Gaskin 1972), little is known of its biology, particularly its reproduction. Gaskin (1972) reported that two females with foetuses were found in New Zealand in winter, whilst Bruyns (1971) recorded a female stranded in September, having just given birth to a calf.

The time of stranding of this specimen together with its size and the degree of ossification of its cranial bones would support the suggestion of a spring-early summer calving.

The largest number of strandings takes place in the summer months in Australia (table 2). The table suggests that whales are absent from Australian coastal waters from August through November and only return in December. The rapidity of the increase in strandings in January suggests that there is a movement either into Australian waters at this time or alternatively that the whales move into the coastal regions where strandings are more likely to occur. The information is not incompatible with the proposition that calving takes place in or adjacent to coastal waters in late spring or early summer gaining some protection for the young from sharks while the female seeks food from the squid shoals which are in coastal waters at that time. The whales then gradually move away with the onset of autumn.

TABLE 2

MESOPLODON LAYARDII: AUSTRALIAN STRANDING RECORDS BY MONTH.
Based on Dixon (1980) and McManus *et al.* (1984). Excludes one undated winter record of Dixon.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12	8	2	2	2	1	3	0	0	0	0	1

Some speculation exists as to whether this was a mother and calf stranding, some residents claiming to have seen two whales keeping company in the area before the stranding. The different stages of decay of the two whales suggest that they died at different times. If the adult was the mother of the calf and she died first then it would be expected that the calf would soon die as it would certainly have been nursing.

The juvenile skull has been deposited in the Tasmanian Museum, and the adult skull is held by the author.

ACKNOWLEDGEMENTS

I am grateful to Mr H. Wapstra, National Parks and Wildlife Service who was responsible for organizing the efforts to obtain these skulls and make them available to me. Ranger R. Le Fevre of the same Service was instrumental in the collection of the skulls from the sites. Mr P. Allbrook is specially thanked for his efforts in recovering the heads, without which they would have been lost.

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PRE-SETTLEMENT EXPLORATION OF TASMANIA AND THE NATURAL SCIENCES: THE CLIVE LORD MEMORIAL LECTURE 1983

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ABSTRACT

PLOMLEY, N.J.B., 1984 (31 viii): Pre-settlement exploration of Tasmania and the natural sciences: the Clive Lord Memorial Lecture 1983. *Pap. Proc. R. Soc. Tasm.*, 118: 69-78. ISSN 0080-4703. 13 Wayne Avenue, Sandy Bay, Tasmania, Australia.

The unfolding of knowledge of Australian natural history as a result of the visits of marine explorers is briefly reviewed, particular attention being paid to Tasmania. The importance of the D'Entrecasteaux and Baudin expeditions is stressed, the unique observations of the Baudin expedition on the Tasmanian Aborigines being emphasised.

The observations of exploring expeditions must form the basis for the study of the ecology of the Australasian region because they provide evidence as to the state of the country before it was disturbed by European settlement.

INTRODUCTION

Exploration had its beginnings in trading and the development of trade routes, and concerned travel by land rather than by sea. For the traveller by land there was the hazard of having to perambulate territories where his reception might be hostile, but the resources needed for his journey were small and he could even carry his trade goods on his own back and walk. The traveller by sea, on the other hand, needed a stout and well found ship which could weather the open sea and sustain a voyage of days, weeks or months, and the perfection of the techniques of sailing and navigation so that a course could be directed from one place to another.

Those most active in diversifying their trading seem to have been the peoples living along the shores of the Mediterranean, and by the beginning of the Christan era they had penetrated not only into Africa but also as far as China along the silk routes. If such traders brought back to their homes any information about the lands they visited, it concerned wonders seen rather than particulars of geography, natural history and the diversity of mankind.

While travel has been stimulated by trading through the ages, over the past two thousand years this primary urge has been overlaid by others. As might have been expected, the first of these was a wish to spread Christianity beyond the confines of Europe, and this wish led to the explorations of the great medieval travellers, of whom Marco Polo was one. A little less than a hundred years later the first of the great sea voyages took place, Diaz rounding the Cape of Good Hope in 1486, Columbus crossing the Atlantic in 1492, and Vasco da Gama sailing round the Cape to India in 1498. For these sea voyages too the stimulus was both trade and the spread of Christianity.

By the beginning of the 18th century, only one large region of the world remained unknown to Europeans, the Pacific. It had been approached both from the east and from the west, the latter as a result of voyages to India by the Portuguese, and subsequently to the East Indies by the Dutch, while the eastern approach followed the incursions by the Spaniards into the Americas. Of these three groups of Europeans, the Portuguese and Spaniards used the conversion to Christianity as a cover for trading ventures, while the Dutch made no bones of their commercial interest.

As the eighteenth century proceeded, two other groups of Europeans took over from the Dutch, Portuguese and Spaniards. These were the British and French. With their entry on the scene, exploration lost much of its association with religion and the underlying core of economic advantage received instead the concealing wrapping of a disinterested search for knowledge about the whole world, the pursuit of Science.

FIRST RECORDS OF THE NATURAL HISTORY OF AUSTRALIA

The first records of the natural history of Australia date from a little less than four hundred years ago, when Dutch sailors began to visit the western and northern coasts of Australia. At that time, that is, at the beginning of the seventeenth century, navigation was still an inaccurate science and one difficult to undertake on shipboard. It was therefore necessary for sailors to pay great attention to natural phenomena, and plants and animals, as guides to the nearness of land, even when that land was known to exist. Thus the Dutch, in proceeding to the East Indies, sailed round the Cape of Good Hope and then made an eastwards passage. Often the landfall was the western coast of Australia and the captain would then sail northwards following it until Arnhem Land was reached, from where he would make for Batavia.

The first certain account of a visit to the Australian coast is that of William Janz who came to the western shores of Cape York Peninsula in the *Duyfken* in 1606. His visit is of some interest because there was a fight between his men and the Aborigines in which there were deaths on both sides. It was the Spanish explorer Torres who, approaching from the east in the same year, discovered the strait which now bears his name and gave the first recognisable accounts of the animals of the region, mentioning the cuscus, the Torres Strait pigeon and the New Guinea dog.

For the first half of the seventeenth century there are a number of references to Australian animals by Dutch seamen. Many of them were birds, but fishes also were mentioned, and occasionally invertebrates such as shells, and plants. The first observation on the customs of the Australian Aborigines dates from this time, the account of the visit of the *Pera* and *Arnhem* to the Gulf of Carpentaria in May 1623 recording that the natives used bones, probably the spines of a stingray, as tips for their spears. The records of these seamen relate only to the western and northern coasts of the continent because although Pieter Nuijts visited the southern coast of Australia in 1627 as far east as the islands of St Peter and St Francis, no record of this voyage is known to exist.

It is to the wrecking of Pelsaert's ship *Batavia* in 1629 on the Abrolhos Islands off the southwestern coast of Australia that we owe the first clear description of a marsupial, the Dama Wallaby *Thylogale eugenii*. Pelsaert also mentions the Brush Bronzewing, and refers to termite mounds.

It was not until 1642 that we find any mention of the natural history of the human inhabitants of Tasmania. When Tasman visited the island in November of that year he not only charted the coastline along which he sailed but he recorded events in his log. Unfortunately these records are very brief and not particularly informative. There is the well known comment that though the Aborigines were not seen it was realised that the island was inhabited because of the smoke of fires and the finding of notches cut into the bark of trees for footholds in climbing them. It was stated that stone implements had been used in cutting these notches, so evidently the Dutchmen were well aware that the natives of Australia, of which Tasmania was then believed to be a part, used stone implements — and that the notches were so widely spaced that the people must be either very tall or had some particular means of climbing. Although Tasman makes some reference to Tasmanian animals, it is hard to be certain about their identity.

It was William Dampier who gave what may be thought of as the first clear descriptions of Australian animals, that is, descriptions in words and pictures which attempted to

distinguish different forms. Dampier visited the Western Australian coast twice, first in 1688 and next in 1699. On his second visit, in his own ship the *Roebuck*, he made both zoological and botanical collections and also described some of his specimens, with illustrations by an artist he took with him. He also described the Aborigines, and one of his comments about them has some relevance for us in Tasmania. He remarked that the men had undergone a ritual removal of some of their front teeth, and later this comment led to confusion about the occurrence of tooth avulsion amongst the Tasmanians.

In this pre-scientific period, as we may refer to it, there developed an interest in the animals and plants of Australia. However, this interest could not develop very far because there was no way of describing living things except as individual forms, that is, their relationships had not yet been made part of the descriptive process. Such a system for the naming of biological material was made possible by the studies of Linnaeus, who in 1735 published his *System Naturae* in which a binomial system of nomenclature was propounded. Under this system those characters of an organism were described which were basic to its structure, that is, an organism received two names, *genus* and *species*, the first name referring to the basic structures distinguishing it from organisms having a different set of basic structures, and the second to other characters which differed among the members of the genus. This method of naming implied that all organisms were related to one another, some closely others distantly. From 1735, then, we might expect to find not only much greater precision in the description of living forms but a greatly increased interest in surveying the natural history of the world.

STUDIES OF TASMANIAN NATURAL HISTORY

The stimulation which the study of the natural world received from Linnaeus's system of nomenclature was complemented by interest in an astronomical problem. This was the determination of the distance between Earth and Sun, a computation which was basic to the study of the universe. How to measure this distance had been a problem which had exercised philosophers since antiquity, and during the seventeenth century mathematical and astronomical research led to the idea of calculating it from measurements of eclipses of the sun by certain of the planets, especially Mercury and Venus. It is a characteristic of transits of Venus that they are double events, a first occurrence being followed by a second eight years later.

Scientific interest in transits was first aroused by observations on Mercury in 1631 and on Venus in 1639. The possibility of using transit data for the calculation of the Earth/Sun distance was realised, and methods for doing so devised, largely as a result of observations made by the astronomer Edward Halley on a transit of Mercury which he witnessed at the island of St Helena in 1677. Astronomers were therefore anxious to make measurements when the next transits of Venus were due in 1761 and 1769.

Largely through the enthusiasm of the French astronomer Joseph-Nicolas Delisle, study of the transits of Venus in 1761 and 1769 became matters of world-wide concern and governmental aid, observations being made at a large number of stations in those parts of the world from which the transits could be observed. In several cases the expeditions observing the transits also made detailed studies of the natural history of the places they visited, and some of these were important in relation to the Australasian region. Thus, when the French astronomer Alexandre-Gui Pingre visited the island of Rodriguez to observe the transit of 1761 he also made a biological survey of the island and collected specimens of its unique fauna and flora.

Another expedition of interest to us was that led by Guillaume-Joseph-Hyacinthe-Jean-Baptiste Legentil de la Galaisiere. Legentil left France in March 1760 with the object of observing the transit at Pondichery, then a French possession in India. By the time he had reached Ile de France in July of that year Pondichery was under seige by the British. After several changes of plan Legentil eventually attempted to reach Pondichery with a French naval force sent to relieve the city but when on arrival at Male on the Malabar coast of India news was received that Pondichery had been captured by the British, the French ships turned back to Ile de France: on 6 June 1761 Legentil was on the high seas, and of course was not able to make any observations of the transit. Cheated of his reward, Legentil decided to remain in the region for another year to gather data relating to

navigation and geography, as well as to undertake studies in natural history. His one year stretched out to eight eventually because he stayed on to make observations of the next transit of Venus in 1769. His eight years in the region were extremely fruitful, and he published their results in a massive two-volume work, in which he dealt with a wide variety of topics such as the customs and religions found in India and the astronomy of the Hindus, as well as researches in Madagascar and in the Philippines, the latter including studies of the soil and its productions, the ethnology of the inhabitants and a history of the Spanish colony. There were also many studies of natural history and of course determinations of latitude and longitude at each of the places he visited. One comment on his work which I think is of particular interest concerns his regard for native peoples — "In his simple manners and absence of pomposity, he showed for the native peoples of every country he visited the most sympathetic understanding".

Study of the observations made of the transit of 1761 did not produce a reliable estimate of the Earth/Sun distance, and so there was wide concern to make a success of the 1769 observations. Not only were more people now interested in the problem, but greater efforts were put into the organisation of expeditions and the development of more accurate scientific instruments for making the measurements. In the discussions involved in preparing for the 1769 transit, the desirability of making observations at stations in the South Seas was emphasised. It was the British who responded particularly to this need, placing the *Endeavour* under the command of James Cook to observe the transit in Tahiti. Cook and his astronomer Charles Green succeeded in making the necessary observations there on 3 June 1769. Thereafter Cook sailed westwards under instructions to look for and explore the eastern coast of Australia, or New Holland as it was then called. On board the *Endeavour* were Joseph Banks and Daniel Carl Solander, two men who were to play a most important part in the study of the natural history of the Pacific in general and of Australia in particular.

Having set the scene, as it were, for the real beginnings of the study of the natural history of Tasmania, it is worthwhile to review very briefly those studies in relation to the marine explorers who visited that place before the island was settled by Europeans. Cook himself did not come until 1777, on his third voyage to the Pacific, but Furneaux spent a few days in Adventure Bay in 1773 during the second voyage.

This group of marine explorers comprised Tasman (1-4 December 1642), Marion du Fresne (6-10 March 1772), Tobias Furneaux (10-15 March 1773), James Cook (26-30 January 1777), William Bligh (20 August-4 September 1788), John Henry Cox (3-11 July 1789), William Bligh (9-22 February 1792), Bruny D'Entrecasteaux (23 April-29 May 1792; 22 January-1 March 1793), John Hayes (26 April-9 June 1793), Bass and Flinders (October 1798-January 1799), and Nicolas Baudin (13 January-27 February 1802).

It will be noticed that these visitors fall into two groups. Firstly, there were two expeditions which each stayed some weeks, a total of about ten weeks by the D'Entrecasteaux expedition and about seven weeks by the Baudin expedition. Hayes stayed at the Derwent about six weeks in 1793, but unfortunately there is no record of what he did there except for his map. Bass and Flinders circumnavigated the island in 1798/99, a voyage which involved no more than occasional landfalls with short periods on shore. The other group comprises six visitors who stayed an average of eight days each, that is, they had come for little more than to replenish wood and water, and the time devoted to collecting specimens of natural history or making observations on the Aborigines was very limited indeed. It might also be noted that all visitors except Tasman, Marion du Fresne and Cox, who spent all their time at or in the neighbourhood of Maria Island, confined their visits entirely or largely to the one small region, Bruny Island and the lands bordering the Derwent River.

The collections made by the "wood and water" visitors were small. Tasman seems to have collected nothing, and Marion du Fresne and Cox only shells. Furneaux's acquisitions were probably little more than the specimens of the Grey Goshawk (*Accipiter novaehollandiae*) and Crested Penguin (*Eudyptes cristatus*) which he took to New Zealand for the Forsters, drawings of them by George Forster being now in the British Museum (Natural History).

There was not an official naturalist with Cook on his third voyage and the collecting of specimens and recording of observations depended largely upon his friend Surgeon William

Anderson. Some of Anderson's collections reached England after the voyage (others were, and may still be, in Russia and in Vienna). Among Anderson's papers there are descriptions of several Tasmanian animals, and John Webber and William Ellis painted some of them. During this visit the first words of Tasmanian language were recorded.

Whatever Bligh may have collected during his visit in the *Bounty* in 1788, collections which probably comprised little more than plants and shells, was almost certainly lost as a result of the mutiny, but during his second visit (actually his third visit because he had first come with Cook in 1777 as master on the *Resolution*) specimens were collected and George Tobin, Third Lieutenant on the *Providence*, painted a number of them, including the echidna, birds (Blue Wren, Tasmanian Robin) and some fish.

Lastly, we may mention the visits of Bass and Flinders to the Furneaux Islands and their circumnavigation of Tasmania. None of their collections seems to have survived the stresses of their voyages except for a wombat which Flinders caught when he visited Preservation Island in the autumn of 1798 to rescue the survivors of the wrecked *Sydney Cove* and took back to Sydney alive. This specimen, preserved in spirits, was sent to Sir Joseph Banks, destined for the collections of the Philosophical Society of Newcastle-on-Tyne. Bass also sent Banks skins and a skull of wombats collected at the Furneaux Islands in October 1798. The visits to Bass Strait by Bass and Flinders also resulted in the recording of information about the mutton birds and penguins seen there, as well as the seals.

THE VISITS OF D'ENTRECASTEAUX AND BAUDIN

It has been seen that the observations made by the short-visit expeditions to Tasmanian shores up to the time of settlement in 1803 were not particularly productive of information about the natural history of the island. At most a few random specimens were collected and some meagre information about the country was obtained.

Quite different, however, were the visits of Bruny D'Entrecasteaux in 1792 and 1793 and of Nicolas Baudin in 1802. These were visits made for the purpose of investigating the natural history of Tasmania and it is to them we owe our first real knowledge of it, with in addition their accounts of the Tasmanian Aborigines, by far the most interesting and most instructive of all those we have of these people in their natural condition. And if these two results of their visits were not enough, we must add the very high quality of the charting of the Tasmanian coastline which was carried out.

In order to understand the work of the French and British expeditions we must compare their organisation. From the middle of the 18th century, official expeditions of discovery included among their objects the gathering of scientific information. This change of emphasis away from the purely commercial was a consequence of the exhortations of Charles de Brosses, whose *Histoire des navigations aux Terres Australes*, published in 1756, forcefully urged the importance of this aspect of a voyage of discovery. Of course treasure and commercial and political advantage were never dropped from view, but the charting of coastlines, the improvement of navigation and the scientific study of countries visited now became activities of very great importance in the work of expeditions. One has only to read the accounts of the voyages of Cook, D'Entrecasteaux, and Baudin to realise that. Yet there was a fundamental difference between the British and French expeditions in regard to the organisation of the scientific work. This is perhaps best shown by comparing Cook's three voyages to the Pacific with those of La Perouse, D'Entrecasteaux and Baudin. With the Cook voyages there was no organised study of the natural sciences but a haphazard and whimsical attack upon it, so that on the first voyage the scientists were Banks and Solander, both primarily botanists; on the second voyage the two Forsters; and on the third voyage there was not an official scientist but the Surgeon, William Anderson, had to do duty for one. In spite of this the scientific work carried out by Banks and Solander and by the two Forsters was superb and of lasting importance. The French exploring ships, on the other hand, carried teams of scientists, so that the main subjects of study — geology, botany and zoology — were fully covered. Thus, with La Perouse there were a botanist, three zoologists and a mineralogist, as well as three artists and a gardener; with D'Entrecasteaux there were five naturalists, the artist Piron and the gardener La Haye; and with Baudin there were three botanists, five zoologists, two geologists, four artists, and

a gardener and his four assistants (a number of the scientists setting out with Baudin had, however, either defected or retired through illness or were dead before his expedition reached Tasmania). The making of charts and the determination of latitude and longitude were the responsibility of naval officers attached to the various ships and were separate from the scientific work.

Not only did the French expeditions carry a wide range of scientists, but the lines upon which they were to work were laid down for them before departure. Here was another important difference between British and French procedures. Both governments took the advice of their learned societies in making arrangements for the scientific studies to be made part of the work of their expeditions, the British Government being advised by the Royal Society of London, and the French Government by the Institut de France and the Museum d'Histoire Naturelle, but while the Royal Society attended only to matters related to the selection of staff, the Institut and Museum also drew up detailed instructions for the work of the French scientists. Of course the naval authorities of both countries issued detailed instructions as to the conduct and procedure of those on board their ships, dealing with such matters as the places to be visited and the routes to be followed, the health of those on board, their food, the conduct to be observed when making contact with other peoples, particularly native peoples, and so on; but even in these matters the British instructions were far more general and left more to the initiative of their captains, while the French tried to cover possible eventualities in their instructions and even laid down a timetable of arrivals and departures at each place to be visited, programmes which were found to be quite unrealistic in practice, as happened with Baudin.

The scientific instructions issued for the French expeditions were also unrealistic in regard to the amount and kind of observations which were required of the scientists, being much too detailed for situations in which an observer had to do the best he could under the conditions actually experienced, yet these instructions do give a picture of the stage of development of particular sciences and the lines along which scientists were thinking at this period. I shall not attempt here to discuss these instructions as they related to geology, botany and zoology, because I want to go into some detail about the history of one special aspect of the natural sciences — the study of man.

The work of the naturalists of the D'Entrecasteaux and Baudin expeditions in Tasmania ranged widely. The principal scientists involved were Labillardiere who came with D'Entrecasteaux, and Peron and Leschenault who came with Baudin. Their collections together with those of other scientists and ship's officers were both important and extensive. It has been reported that the work of the Baudin expedition on the coasts of Tasmania and the Australian mainland resulted in sending back to France more than 22 000 specimens, comprising dried plants and preserved animals, ethnological material, living animals and plants, mineral specimens and so on. These collections provided material for study for many years, so that we find that the first description of a number of Tasmanian species was one outcome of these two expeditions.

The botanical work of the D'Entrecasteaux and Baudin expeditions was undertaken by Labillardiere and by Leschenault. Labillardiere's work was published in two large volumes in 1804 and 1806, illustrated by a number of plates, descriptions of a few Tasmanian species having appeared earlier in Labillardiere's general account of the voyage of D'Entrecasteaux which was published in 1802. Leschenault's botanical studies on the Baudin expedition did not appear in book form , except for a memoir on the botany of the Australian region which appeared in the VOYAGE, but were published in a series of memoirs in the *Annales* of the Museum d'Histoire Naturelle in Paris in 1810/11. The first comprehensive British collections of plants from Tasmania and the islands of Bass Strait were those made by Robert Brown between 1802 and 1804, and were described in his PRODROMUS FLORAE NOVAE HOLLANDIAE ET INSULAE VAN-DIEMEN (1810).

The zoological work of the D'Entrecasteaux expedition also fell largely on the shoulders of Labillardiere, and we find in the VOYAGE mention of a number of Tasmanian species: birds, including the Black Swan, mammals, fish and so on. Many of the specimens collected were later described in the literature, for example, the insects were named by Fabricius.

In keeping with the huge number of specimens collected during the Baudin expedition, we find an extensive literature dealing with the description of Australian and Tasmanian species. By the time the expedition had reached Tasmania in January 1802, the naturalists had been reduced to two, Peron and Leschenault — Bory de Saint Vincent, Delisse, Dumont and Michaux had either defected or had been left ill at Ile de France on the voyage out; Riedle, gardener-botanist, died at Timor; the zoologist Levillain died at sea shortly after the expedition left Timor on its way to Tasmania, and Mauge was to die at Maria Island during the Tasmanian visit. The two geologists, Bailly and Depuch, went through the whole Australian experience, though Depuch was to die at Ile de France on the voyage home. Of the five artists, three left the expedition at Ile de France on the voyage out, and only Lesueur and Petit remained with it for the whole voyage. It says much for Peron and Leschenault that they not only completed the voyage but made such huge collections. It must be added that the leader of the expedition, Nicolas Baudin, was also interested in natural history and made collections. This was no new interest for him because he had already been employed in the West Indies making natural history collections, mostly of plants and insects, for the Emperor of Austria and for the Museum d'Histoire Naturelle in Paris. Several of his officers were also interested in natural history, made collections, and assisted the naturalists.

Not only were Peron and Leschenault active in collecting natural history material, but they absorbed themselves in describing it. Leschenault did not return to France with the expedition but remained in the East Indies for quite a time collecting plants there. When he did return to France he worked on all these collections at the Museum d'Histoire Naturelle in Paris. Peron was not entirely alone as zoologist, the natural history artist Lesueur collaborating with him in a great deal of his work. Peron's interests were wide ranging, covering most groups of animals. He published descriptions of coelenterates; his notebooks contain descriptions of reptiles, amphibians and fishes, including new species, as well as many invertebrates, and only birds received little attention from him, though specimens were collected throughout the voyage; he published memoirs on the temperature of the sea, on the zoology of the Australian region, on seals and their relatives, and on dysentery, and he reported at length on the physical features, geology and natural history of Maria Island and of other places. He even made a collection of lichens in Tasmania!

Three other points should be mentioned before dealing with the anthropological work of the Baudin expedition. These are the charting and geographical work, the geological observations, and the work of the artist-naturalist Charles-Alexandre Lesueur. The basic charting of southeastern Tasmania had been carried out by Beautemps-Beaupre during D'Entrecasteaux's visits in 1792 and 1793. Baudin's marine surveyors, Pierre Faure and Charles-Pierre Boullanger, together with Louis de Freycinet, one of the officers on the *Naturaliste*, extended and corrected Beautemps-Beaupre's charts of southeastern Tasmania, and in addition surveyed the eastern and northeastern coasts of the island, including the southern part of the Furneaux Islands and Port Dalrymple, and the far northwestern coast, the Hunter Islands and King Island.

Geological observations were undertaken by Louis Depuch and Charles Bailly, and among the records of the expedition there is a catalogue of mineral substances collected by Bailly. Peron was also interested in geology and in his report on Maria Island he deals with the geology of the region. To Peron is also due the first reference to Tasmanian fossils, when he mentions that he collected fossil shells in marine deposits lying between the Derwent and Goat Hill.

Lastly, some mention must be made of the natural history drawings and paintings of Lesueur. These were of a standard which has hardly been surpassed, and he executed literally hundreds of them. Few have been published, but the bulk of Lesueur's work is still in existence, largely in the collections of the Museum d'Histoire Naturelle at Le Havre. These superb drawings and paintings certainly should be published, in spite of the difficulties in reproducing them in the very fine detail and delicate colouring of the originals.

ABORIGINAL MAN AS SEEN BY THE PRE-SETTLEMENT EXPLORERS OF TASMANIA

At least from the time of Cook, the leaders of official expeditions to the Pacific received instructions "to observe the genius, temper, disposition and number of the natives, and endeavour by all proper means to cultivate a friendship and alliance with them", and such instructions were given to both the British and French explorers in almost identical terms.

It will be convenient to consider the observations made on the Tasmanian Aborigines by the marine expeditions as falling into two groups: one, the wood-and-water visitors and the other those of the D'Entrecasteaux and Baudin expeditions. The wood-and-water visitors were Tasman, Marion du Fresne, Furneaux, Cook, Bligh and Cox. All of them made useful comments on the people they saw, but in no case were the observations sufficiently prolonged or recorded in enough detail to obtain any but scraps of information about the Aborigines.

Before dealing with the impressive observations made by the D'Entrecasteaux and Baudin expeditions, it will be as well to take a look at the state of anthropological knowledge during the second half of the 18th century. As a scientific study distinct from the curious tales of travellers concerning the peoples of the Earth, anthropology came into its own with the work of Johann Friedrich Blumenbach (1752-1840), Professor of Comparative Anatomy at Gottingen, who from the mid-1770's carried out pioneer studies on the varieties of man. One of those influenced by him was Johann Reinhold Forster (1729-1798) who sailed with Cook on his second voyage to the Pacific, whose peoples he was to describe in considerable detail, providing a body of information about them which has scarcely been surpassed.

Blumenbach's work exerted considerable influence on explorers and travellers who were interested in the study of man, and this can clearly be seen in the instructions issued for the scientists of the French expeditions to the Pacific. La Perouse was the first: he was instructed to report not only on a number of matters which Cook had dealt with incompletely but also to make a wide range of other enquiries. It is understandable that it was the medical men and not the zoologists who were to concern themselves with the study of man: in the instructions given the scientists only human anatomy was mentioned, attention being drawn to the need for observations on the skeleton of man, the proportions of the body, age at puberty and the duration of life. On the other hand, the instructions given to the medical officers asked for a wide range of information about human anatomy and physiology, hygiene, disease, materia medica and surgery. In all this, however, the social organisation of native peoples received no mention.

When D'Entrecasteaux left France in September 1791 on his voyage in seach of the missing La Perouse, the scientific instructions issued for the voyage were very much like those given to La Perouse. It seems, however, that while still emphasising the importance of Blumenbach, that is, observations on comparative anatomy, there were also to be enquiries into the social organisation of native peoples. Some enquiries dealt also with matters which might be of use to Europeans, for example, the botanists were asked to note what species of plants were used in the manufacture of cords and string, and whether such plants could be grown in the West Indies, that is, in the French colonial possessions there.

For the observations on the Tasmanian Aborigines made by the D'Entrecasteaux expedition we must depend at present largely on Labillardiere's account of the voyage (1802) and to a less extent upon that published by Rossel (1808), one of the naval officers. Unfortunately, no one has yet examined the extensive manuscript records of this expedition. My own preliminary study of them has shown that they contain a great deal of information which is not to be found in the published accounts and which is of considerable value.

When the Baudin expedition came to be organised, the instructions issued for the study of man covered a much wider range than previously. They included a memoir by Joseph-Marie Degerando entitled "On the observation of savage peoples." Degerando's thesis was that the proper way to study man was to observe his whole way of life, and to do this the observer must first learn the language of the people he was studying. Only in this way

could he come to know them thoroughly, both individually and as a community. It was a brilliant idea and the basis of modern methods of studying native peoples, but it was to be 150 years before it was put into practice. It was also a methodology which was quite impractical in respect to an expedition such as Baudin's which stayed for only a short time in any one place and also had to deal with a wandering people. The long association needed to gain an adequate knowledge of the language and to study a community in depth was just not possible and it is no wonder that the Baudin expedition followed the old routine of casual observation, with remarks upon the physical characteristics of the Aborines and their manufactures and way of life. Peron did not even apply to his observation of the Aborigines the same level of scientific exactness which he gave to his studies of natural history, so that he failed to enquire systematically into any matter concerning them. Others on the ships did better, for example, Baudin, the Commander. Peron, did however, perform one great service to studies of the Tasmanian Aborigines. He showed them to us in his writing as a living people with such fascinating descriptions as that of Oure-Oure, the young woman he met with her family at Port Cygnet, Arra-Maida whom he met in company with a number of other women on North Bruny, and the party of men he met on Maria Island, an encounter during which tension was high on both sides.

From the records of all the marine expeditions which visited Tasmania before the island was settled by Europeans, we can build up a picture of the characteristics, manufactures and way of life of the Aborigines. This record is very incomplete but without it we would know almost nothing about the living people who were the original inhabitants of this island. Of all these records only those of the D'Entrecasteaux and Baudin expeditions provide us with any real information about the people, because they were the only ones to stay any length of time. All other explorers stayed too short a time to make anything more than casual observations. And this body of observation gains importance in view of the lack of information about the living people to be found in the records of the settlers, excepting only the journals of G.A. Robinson.

The sorts of information about the Tasmanian Aborigines to be gained from the records of the pre-settlement explorers covers a wide range — physical characteristics, population structure, sickness and injury, dwellings, weapons, implements and manufactures, fire making and fire setting, food and its preparation, language, social organisation and customs, and the interactions of Aborigines and Europeans. As would be expected from the brief contacts between the Aborigines and the wood-and-water visitors, their records are scrappy and often indefinite, but added together they do provide worthwhile information. It is only when the records of the D'Entrecasteaux and Baudin expeditions are studied that any real picture of the living people emerges, but even that picture is at present incomplete because the D'Entrecasteaux records have not yet been examined in detail. The D'Entrecasteaux records gain importance from the fact that the members of this expedition could observe the living people at their camping places, whereas Baudin and his people could not do so because of the suspicions held by the Aborigines about the intentions of the Europeans, an attitude which had developed since the visit of D'Entrecasteaux because of the incursions into the region by 1802 of sealers and kangaroo hunters from Port Jackson.

Perhaps the most striking impression to be gained from the Baudin records is that at the time of this visit the Tasmanian Aborigines were still a normal living people. They showed no signs of decline or degeneration, a view emphasised by the large number of children among them, as well as by the absence of evidence of disease. The technology of the people was simple but it was quite adequate to support active living in the Tasmanian environment. The records provide clear information about many aspects of this technology, though unfortunately not all, for there are a number of points upon which further information is needed, and could have been provided if Peron has been as diligent in recording anthropological data as he was in describing the fauna of Tasmania. It must be remembered that the people whom Baudin was observing were living by the sea, so statements about their food relate almost wholly to the products of the sea and there are few references to foods obtained from the land.

The want of a common language, so that gesture had to be the means of communication, was the real obstruction to mutual understanding between Frenchmen and Aborigines — as Degerando had realised — and so there is little information in the Baudin and other records

about the social structure and culture of the Tasmanians. It seems that their social organisation was of the simplest, little more than assemblages of families. That they recognised group relationships is shown by the patterns of scarification with which they adorned their bodies, yet they seem not to have had chiefs in the political sense, only leaders to whom they deferred — perhaps the term *seigneur* would designate these individuals suitably. It seems that there were territorial limits for the activities of the various bands but that a territory was by no means an exclusive property, because travel across territories seems to have been freely allowed, witness the meeting with the Bruny Islanders on the mainland shore opposite Maria Island, and the absence of injuries due to warfare from the bodies of the men.

That the Tasmanians had a strong religious life is made clear from the structure of their tombs, two of which were found on Maria Island. The importance of funerary procedures is shown particularly by the exact form of the tombs and by the markings on the bark covering, which were similar in pattern to the scarifications with which they adorned their bodies.

It seems fitting to conclude a Clive Lord Memorial lecture with some general remarks on the study of the natural history and original inhabitants of Tasmania. As a basis for any studies of natural history today, every attempt should be made to place the present in the context of the past. For a knowledge of the past, at any rate that recent past out of which the present has developed, we must go to the records of the explorers who saw the country before it was occupied by the invading Europeans. The use of an explorer's records is usually difficult: scribbled notes, localities not stated with sufficient precision for clear identification, the record written in a language foreign to the student, the text overwritten and difficult to decipher. Yet the labour of untangling meanings and the boredom of making one's way through seeming endless irrelevancies, usually produces in the end information which is of great value and worth all the time spent on the work. And if the written record is supplemented by a pictorial record, however crude, its value is enhanced.

While the above remarks record my experience with the records of the marine explorers, they apply generally to the records of all explorers, because we need information about the whole country, not just its seaboard as revealed by the generality of marine expeditions. Those who study the Tasmanian environment as well as those who are interested in the larger Australian environment should examine the records of all the explorers of the country, whether they may have been making an official exmaination of some unknown region or just looking for new grazing land. And for information about the Aborigines, an explorer's records are often of the greatest value, providing perhaps the only information about the life of people who have now vanished. So far as the Tasmanian Aborigines are concerned a thorough examination of the D'Entrecasteaux record is urgently needed.

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OBSERVATIONS ON THE FEEDING PREFERENCES OF TWO SPECIES OF TASMANIAN TERRESTRIAL AMPHIPODS (CRUSTACEA: AMPHIPODA: TALITRIDAE)

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(with three tables)

ABSTRACT

MORTON, H.P. and RICHARDSON, A.M.M., 1984 (31 viii): Observations on the feeding preferences of two species of Tasmanian terrestrial amphipods (Crustacea: Amphipoda: Talitridae). *Pap. Proc. R. Soc. Tasm.*, 118: 79-84. ISSN 0080-4703. Department of Zoology, University of Tasmania, Hobart, Tasmania, Australia.

The food preferences of two species of terrestrial amphipod, *Talitrus (Keratroides) vulgaris* and *Talitrus (Keratroides) angulosus*, from near Tooms Lake, Tasmania were investigated. Both species preferred the leaves of *Olearia argophylla* to those of *Eucalyptus obliqua*, decomposed leaves to fresh leaves, and leaves artificially hydrolysed in hydrochloric acid to fresh leaves. Sterilization did not affect their preferences. No differences were detected in the preferences of the two species. These terrestrial amphipods do not appear to be attracted to living bacteria and fungi, but rather to the hydrolytic effect which they have on the leaves.

INTRODUCTION

Terrestrial amphipods are common members of the litter fauna in the wetter forests of Australia, New Zealand, Japan and a number of localities in the Pacific (Bousfield 1982). They share this habitat with a large number of species which often exhibit a low degree of trophic specialization (Anderson 1975). Recent work (Friend 1980) has shown that the amphipod fauna in Tasmanian forests is diverse and that it is not uncommon to find three or four species present together in the litter at a single site. This raises the problem of how these species avoid competition with each other, and although spatial separation has been demonstrated between two Tasmanian species (Friend & Richardson 1977), the possibility that they have different food preferences must be considered.

In temperate forests, part of the litter consists of a collection of leaves in various stages of decay, more or less reflecting the proportions of leaf species in the canopy. The process of decay begins while the leaf is still on the tree (Dickinson & Pugh 1974), but when the leaf reaches the floor the change in microclimate allows a rapid colonization of the surface of the leaf by fungi and bacteria which primes the leaf for attack by macro-arthropods, including amphipods. Laboratory experiments have shown not only clear preferences by mites (Mitchell & Parkinson 1976) collembolans (Visser & Whittaker 1977) and aquatic amphipod species (Barlocher & Kendrick 1973a) for leaves colonised by specific fungi, but also increased growth and fecundity when arthropods are fed on the preferred fungi (Barlocher & Kendrick 1973b, Booth & Anderson 1979). Changes in available nitrogen and phosphorus levels following microbial attack (Satchell & Lowe 1967) may also alter leaf palatability, and therefore the extent of microbial attack.

Thus to state simply that a macro-arthropod feeds on decomposing plant material ignores the subtle differences inevitably present between substrates. When these are recognised, and the great heterogeneity of leaf litter is considered, the apparent similarities in food preferences of coexisting mesofauna may only be superficial.

Friend (1980) studied two species of amphipod in a wet gully near Tooms Lake in eastern Tasmania. The two species, *Talitrus (Keratroides) vulgaris* Friend, 1979 and *Talitrus (Keratroides) angulosus* Friend, 1979, both apparently feed on decaying leaves, preferring these to other components of the litter. This paper records a further investigation of these two species, using animals and food from the same site.

Feeding Preferences of Tasmanian Terrestrial Amphipods

Preferences for partly decomposed leaves over sterile or freshly fallen ones have been recorded for millipedes (Lyford 1943), earthworms (Satchell & Lowe 1967), aquatic caddis fly larvae (Mackay & Kalff 1973) and aquatic amphipods (Kaushik & Hynes 1971). These preferences can be attributed to either the physical presence of microbial communities, or the chemical changes in the leaf resulting from their hydrolytic actions. As well as examining the effect of leaf species on palatability, we have attempted to separate these two effects and to determine their influence on palatability.

METHODS

Several choice experiments of the same basic design were used to assess food preferences. The experiments were performed in Petri dishes with a base of moistened Plaster of Paris. The leaves used were collected from the Tooms Lake site and stored at 10°C until use. Discs of the leaves to be tested (1.5 cm diameter, cut to avoid the mid-rib) were oven dried at 60°C for 48 hours, and weighed individually prior to use. The test substrates were arranged, underside down, around the edge of the dishes. Duplicates of each substrate were placed in each dish, positioned opposite each other to eliminate spatial preferences. All substrates were sprayed with water before the animals were added to the dish.

Approximately ten animals of the selected species were weighed and added to each dish, where they were allowed to feed for 3-5 days at 10°C. The substrates were then removed, dried as before, and reweighed. The weight losses were compared with those from identical discs which had not been exposed to the animals. Consumption was expressed as mg consumed. g animal^{-1}.day^{-1}.

In the first series of experiments, the animals were given a choice between the leaves of the two principal tree species at the site, *Olearia argophylla* F. Muell. and *Eucalyptus obliqua* L'Herit., at two stages of decomposition. Freshly fallen leaves (green, rigid, and with little sign of microbial attack) were compared with leaves at an intermediate stage of decomposition (browning but still rigid, with signs of moderate microbial attack). It was not possible to compare leaves at a later stage of decomposition, since the *Eucalyptus* leaves were too fragile to handle. For each amphipod species, ten trials were run in which all test substrates were offered.

To separate the effects of the presence of microbial communities from their catalytic effects, the preferences of the animals for partly decomposed leaves were compared with those for similar leaves autoclaved at 125°C for 1 hour (Howard & Frankland 1974). Fifteen trials were conducted on both amphipod species.

To distinguish between the purely chemical changes in the leaves resulting from microbial attack and structural, biochemical or biological changes, the effect of an artificial hydrolysing agent (hot HCl) on the palatability of *Olearia* leaves and filter paper was examined. Preweighed discs of *Olearia* and filter paper were added to beakers of HCl (1.0N for filter paper, 2.0N for leaves) or distilled water. The treatments used were identical to those used by Barlocher & Kendrick (1975) and the higher concentrations of acid used on the leaves reflects their greater resistance to hydrolysation. The beakers were incubated at 90°C for 4 hours (leaves) or 45 minutes (filter paper). Duplicate beakers with identical contents were left at room temperature. The discs were then rinsed repeatedly in distilled water before use in the experiments. Ten trials, using all substrates (leaves and filter paper treated with hot HCl, cold HCl, hot water and cold water) were made for each amphipod species.

RESULTS

The mean consumption rates of each leaf species at two stages of decomposition are shown in table 1a. A three-way analysis of variance (table 1b) revealed significant preferences for *Olearia* leaves, and partly decomposed leaves. There is a significant interaction between these two factors, which is due to the higher consumption of fresh *Olearia* by *T. vulgaris*.

TABLE 1

EFFECT OF LEAF SPECIES AND STAGE OF DECOMPOSITION ON AMPHIPOD FEEDING RATE.
(a) Effect of leaf species and stage of decomposition on the rate of consumption by the two amphipod species, expressed as mg of leaf consumed.g animal^{-1}.day^{-1} at 10°C, (x±SD), n=10.
(b) Summarised analysis of the variance of the above data.

(a)

Amphipod species	*Talitrus vulgaris*		*Talitrus angulosus*	
Leaf species	*Olearia*	*Eucalyptus*	*Olearia*	*Eucalyptus*
Freshly fallen	45.80±9.49	0.01±0.01	10.59±2.28	0.02±0.01
Partly decomposed	30.13±4.19	27.30±3.71	28.65±3.68	10.23±2.36

(b)

Factor	F	d.f.	Significance
Leaf species	13.46	1,72	$P < 0.001$
Decomposition stage	5.83	1,72	$P < 0.05$
Amphipod species	0.03	1,72	NS
Leaf species × decomposition stage	4.39	1,72	$P < 0.05$

The effect of sterilization on consumption rate is shown in table 2a. Analysis of variance (table 2b) showed that although substrate type did not influence consumption rates significantly, overall consumption by *T. angulosus* was significantly greater than by *T. vulgaris*.

TABLE 2

EFFECT OF LEAF STERILIZATION ON AMPHIPOD FEEDING RATE.
(a) Effect of leaf sterilization on the feeding rate of the two amphipods expressed as mg leaf consumed. g animal^{-1}.day^{-1} at 10°C (x±SD), n=15.
(b) Summarised analysis of variance of the above data.

(a)

K	*Talitrus angulosus*	*Talitrus vulgaris*
Natural leaves	40.76±12.24	31.45±9.50
Autoclaved leaves	43.56±17.65	29.21±13.00

(b)

Factor	F	d.f.	Significance
Substrate type	0.006	1,56	NS
Amphipod species	11.66	1,56	$P < 0.01$

The mean consumption rates for each of the hydrolysed substrates are shown in table 3a and analysis of variance (table 3b) showed that changes in the composition of the leaves and filter paper produced by hydrolysis significantly increased palatability, but no significant differences in preferences existed between the two amphipod species, or in their preferences for leaves or filter paper.

TABLE 3

EFFECT OF HYDROLISATION ON AMPHIPOD FEEDING RATE
(a) Effect of hydrolisation on the feeding rate of the two amphipod species expressed as mg consumed.g animal^{-1}.day^{-1} at 10°C (x±SD), n=10.
(b) Summarised analysis of variance of the above data.

(a)

Amphipod species	*Talitrus angulosus*				*Talitrus vulgaris*			
Treatment	Hot HCl	Cold HCl	Hot H_2O	Cold H_2O	Hot HCl	Cold HCl	Hot H_2O	Cold H_2O
Olearia leaves	30.18 ±11.45	1.60 ±3.08	0.15 ±0.34	0.01 ±0.01	31.64 ±11.42	4.45 ±8.09	0.66 ±1.59	0.01 ±0.01
Filter paper	28.19 ±8.53	0.40 ±1.26	1.43 ±4.29	0.02 ±0.01	31.30 ±10.09	1.23 ±2.11	3.59 ±6.03	0.15 ±0.46

(b)

Factor			Significance
Substrate treatment	243.45	3,144	$P < 0.001$
Substrate type	0.05	1,133	NS
Amphipod species	1.88	1,144	NS

DISCUSSION

The clear preference of both amphipod species for *Olearia* over eucalypt leaves illustrates the importance of leaf characteristics in determining palatability. In a study of millipede food choices, Lyford (1943) found a strong preference for basswood leaves compared to birch, maple and oak, and although he attributed this to differences in their calcium content, he recognised that also involved were the organic structure of the leaf, the proportion of lignins, cutins and similar structural compounds. Variation in protein and sugar content (Laverack 1960), tannin and polyphenol content (King & Heath 1967), nitrogen and carbohydrate content (Satchell & Lowe 1967) are among other chemical factors implicated in leaf palatability, but the relative importance of these factors undoubtedly varies with the species of macro-arthropod decomposer involved.

Very little work seems to have been done on the preferences of leaf litter arthropods for the leaves of Australian trees. Using a behavioural approach, Devitt (1981) showed that three species of terrestrial amphipod preferred the leaves of *Bedfordia salicina* to those of *Eucalyptus obliqua*. The thick, waxy cuticle of eucalypt leaves, and the high polyphenol content and the presence of complex aromatic oils (Kelly 1969) probably act as a deterrent to macro-arthropod attack. Casual observation in the laboratory suggests that the thickness of the cuticle may be important in determining preferences. Amphipods generally attacked *Bedfordia* leaves from the underside, where the cuticle was thinner, and the material between the veins was consumed in preference to vascular bundles. Since the cuticle of eucalypt leaves covers both sides more or less equally, this must reduce their attractiveness to the animals.

Preference for partly decomposed leaves has been recorded in a number of other macro-arthropod decomposers. Kheirallah (1979) found that the preferences of millipedes for various leaf species changed as the leaves decomposed. Similarly, Lofty (1974) found that the preferences of *Lumbricus terrestris* reversed after leaves had weathered. Dickinson & Pugh (1974) suggested that changes in leaf palatability during decomposition may be attributed to the following factors: (1) decrease in polyphenol content, (2) decrease in C:N ratios, (3) hydrolysis of surface sugars, and (4) the presence of bacterial and fungal colonies. Since leaves will differ in their structure and chemical composition, the decomposition process will act differentially on leaf species.

Two major mechanisms are involved in leaf conditioning by micro-organisms: (1) the conversion of plant tissue into microbial tissue, and (2) the partial digestion of plant tissue into sub-units digestible by macro-arthropod grazers (Barlocher & Kendrick 1975). Either, or both, of these mechanisms may be instrumental in explaining the preference of most grazers for "conditioned" leaves.

Sterilizing techniques have been used previously to assess the importance of microbial production in determining preferences for "conditioned" leaves. The effects of autoclaving may not be confined simply to killing the microbial colonies, since Howard & Frankland (1974) also noted chemical changes in autoclaved leaf litter. However, table 3 shows that autoclaving leaves did not significantly alter their palatability. In similar experiments, Kaushik & Hynes (1971) and Mackay & Kalff (1973) found that the detritus feeders which they studied preferred natural to autoclaved leaves. This was interpreted as confirmation of the importance of microbial production in determining leaf palatability, leaf attractiveness being influenced by microbial growth, not just the physical presence of microbial communities.

This conclusion cannot be supported from the present study, where it appears that amphipods do not discriminate between leaves with viable microbial colonies and those with dead colonies. Therefore, either the physical presence of micro-organisms, or their catalytic effects, influence, at least partially, the palatability of leaves to terrestrial amphipods. The results presented in table 2 suggest that hydrolytic effects not only change leaf composition, but increase palatability, even in the absence of living microbial colonies. Hydrolysis by HCl can only represent one of the processes enhancing palatability which micro-organisms bring about during the decomposition of leaf material (Dickinson & Pugh 1974), and this does not totally remove the possibility that the presence of microbial colonies also influences the attractiveness of leaves. Barlocher & Kendrick (1975) demonstrated that HCl hydrolysis greatly increased the palatability of leaves and filter paper to the aquatic amphipod, *Gammarus pseudolimnaeus*.

This study has failed to demonstrate any differences between the dietary preferences of *Talitrus vulgaris* and *T. angulosus*. Since *T. angulosus* is found in the fermentation layer of the soil-litter system (Friend & Richardson 1977), it might have been expected to show a preference for leaves at a later stage of decomposition. The absence of any such preference does nothing to alter the suggestion (Friend & Richardson 1977, Friend 1980) that it is competition for habitat space which has brought about the niche separation between the two species.

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MILLIPEDES FROM AUSTRALIA, 7: THE IDENTITY OF THE GENUS *LISSODESMUS* CHAMBERLIN, WITH THE DESCRIPTION OF FOUR NEW SPECIES FROM TASMANIA (DIPLOPODA, POLYDESMIDA, DALODESMIDAE)

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(with fifteen text-figures)

ABSTRACT

JEEKEL, C.A.W., 1984 (31 viii): Millipedes from Australia, 7: The identity of the genus *Lissodesmus* Chamberlin, with the description of four new species from Tasmania (Diplopoda, Polydesmida, Dalodesmidae). *Pap. Proc. R. Soc. Tasm.*, 118: 85-102. ISSN 0080-4703. Instituut voor Taxonomische Zoölogie, Zoölogisch Museum, Universiteit van Amsterdam, The Netherlands.

The monotypic *Lissodesmus modestus* Chamberlin, 1920, is redescribed from nearly topotypical material, and four new species, *L. adrianae*, *L. alisonae*, *L. perporosus* and *L. margaretae*, all from Tasmania are added to the genus. *Australopeltis* Johns, 1964, based on *Pseudoprionopeltis martini* Carl, 1902, from Victoria, is considered a synonym of *Lissodesmus* (new synonymy). Some remarks are made on the classification of the non-paradoxosomatid Polydesmida of Tasmania.

INTRODUCTION

During a trip through Tasmania towards the end of November 1980 (Jeekel 1981), the author and his wife at various localities collected a number of dalodesmid millipedes, which were conspicuous by the frequency of their occurrence, their relatively major size, and their light brown-orange colour. In the field these specimens looked very much alike, apart from some slight differences in size, but upon closer examination no less than four distinct species were recognized.

Up to now six species and as many genera of the order Polydesmida not belonging to the family Paradoxosomatidae have been described from Tasmania. All are known only from their type locality and material and have been described by Silvestri (1910), Chamberlin (1920), Verhoeff (1936) and Jeekel (1982). These are: *Asphalidesmus leae* Silvestri, 1910 (Hobart); *Atopodesmus parvus* Chamberlin, 1920 (locality unknown); *Lissodesmus modestus* Chamberlin, 1920 (Russell Falls); *Tasmanodesmus hardyi* Chamberlin, 1920 (locality unknown); *Tasmaniosoma armatum* Verhoeff, 1936 (Lake Leake); and *Gasterogramma psi* Jeekel, 1982 (Hellyer Gorge).

The first two genera are not considered in the discussion on the generic position of the collected species. As noted below, there is much evidence to support the exclusion of *Asphalidesmus* and *Atopodesmus* from the Dalodesmidae, thus leaving the four remaining genera as true members of the family.

Among these, *Gasterogramma* is quite distinct from the material at hand. Its cylindrical body lacks paranota almost completely, the relative length and width of the podomeres of the male are different and the gonopods are quite characteristic. Its status was amply discussed in a previous paper of the present series.

Tasmaniosoma is distinct in having 19 body somites and the long tarsi exceed all other individual podomeres in length. The genus is well characterized by the structure of the gonopods which have been illustrated.

Unfortunately, no illustrations have been published of the gonopods of *Tasmanodesmus* and *Lissodesmus*, and on that account the position of these two genera within the family

Dalodesmidae is uncertain. With regard to *Tasmanodesmus* it must be concluded that the description of this genus and of its type-species cannot be reconciled with the material at hand. Chamberlin described the gonopods as "telopodites long, split from the distal end to near middle of length into three branches, the middle (seminiferous) of these the longest, slenderly tipped, branches not coiled". This statement does not tally with the structure of the gonopods in the collected species, in which the solenomerite is just one of several shorter branches. Moreover, the legs in *Tasmanodesmus* are described as having long tarsi as in *Tasmaniosoma*.

Therefore, the only generic name possibly eligible for the collected species is *Lissodesmus*. Fortunately, specimens collected quite near the type locality of *L. modestus* match its description quite well and there is little doubt that *Lissodesmus* is the proper generic name for the four species.

Moreover, the four species are clearly congeneric with *Pseudoprionopeltis martini* Carl, 1902, described from Melbourne, and more recently recorded from Cockatoo Creek, Victoria, by Johns (1964). The latter author erected the subgenus *Australopeltis* for this species, restricting the nominate subgenus *Pseudoprionopeltis* Carl to some New Zealand species. *Australopeltis* has since been raised to generic rank, and quite correctly so, by Hoffman (1980). As *Lissodesmus* and *Australopeltis* cover the same generic concept, the latter name falls as a junior subjective synonym of *Lissodesmus*.

In addition to the four species collected, a fifth species of *Lissodesmus* was discovered among material received on loan from the Tasmanian Department of Agriculture.

The holotypes and some paratypes of the new species have been deposited in the Tasmanian Museum and Art Gallery, Hobart. Some paratypes of *Lissodesmus margaretae* and the remainder of the material under report are preserved in the Zoological Museum at Amsterdam.

CLASSIFICATION OF THE GENERA *ASPHALIDESMUS* SILVESTRI AND *ATOPODESMUS* CHAMBERLIN

Recently the known non-paradoxosomatid Polydesmida of Australia were referred to the family Dalodesmidae, although with some reservation with regard to the status of those genera of which the male characters were not or insufficiently known (Jeekel 1981). The association of the latter genera with the Dalodesmidae seemed the most logical solution in view of the apparent lack of evidence to the contrary and the probability inferred by the sympatry of the taxa involved.

In his classification of the Diplopoda, Hoffman (1980) referred the Tasmanian genera *Asphalidesmus*, *Lissodesmus* and *Tasmaniosoma* to the Dalodesmidae, assuming a close relationship or even identity of *Asphalidesmus* and *Tasmaniosoma*, whereas *Atopodesmus* was listed under the Polydesmidae of uncertain status and family position, and *Tasmanodesmus* was left out of consideration.

A careful re-evaluation of the available generic and specific descriptions has now led to the conclusion that these recent concepts were an oversimplification of the actual situation. In fact, there appears to be strong evidence that *Asphalidesmus* and *Atopodesmus* should be excluded from the Dalodesmidae.

Although other male characters of *Asphalidesmus* have been described, it is not known whether the legs have the modified setae characteristic of almost all Dalodesmidae. From the absence in the description of any statement on this particular feature it is inferred that the legs have normal setae.

That *Atopodesmus* is closely related to *Asphalidesmus* seems quite obvious, in spite of the absence of information on its male characters. The two taxa share some non-sexual details which at the same time distinguish them quite well from the dalodesmid genera reported from Tasmania. Both genera are characterized by having the paranota of the second somite relatively strongly developed, produced anteriorly and posteriorly and sloping downwards so as to form a collar-like structure embracing the head and the first tergite.

Both genera are represented by small forms of about 6 mm length, whose metatergites are covered with numerous setiferous granules. The conclusion must be that the two genera are either aberrant Dalodesmidae or should be excluded from that family.

With regard to this question a comparison between the polydesmid faunae of Tasmania and South Africa gives a clarifying hint. South Africa has, besides the Paradoxosomatidae and Gomphodesmidae, the taxonomic status of which is irrelevant to the problem at hand, three polydesmoid groups: the Pyrgodesmidae, the Dalodesmidae and the Vaalogonopodidae. The first of these is represented by a single genus and species. The Dalodesmidae of South Africa has numerous genera and species; the endemic Vaalogonopodidae consists only of a small number of species referred to two closely related genera: *Phygoxerotes* Verhoeff, 1939, and *Vaalogonopus* Verhoeff, 1940.

To refer *Asphalidesmus* to the Pyrgodesmidae is out of the question considering the gonopod structure and other morphological particulars. However, a comparison of the descriptions of *Phygoxerotes* and *Vaalogonopus* on the one hand, and of *Asphalidesmus* and *Atopodesmus* on the other, reveals a remarkable degree of similarity in general habit and in the gonopods. This, combined with the remarkable faunistic parallelism of the Polydesmida of South Africa and Tasmania, seems to justify the conclusion that *Asphalidesmus* and *Atopodesmus* are referable to the Vaalogonopodidae rather than to the Dalodesmidae.

So far, mystery has surrounded the status of the Vaalogonopodidae within the polydesmid system. When Verhoeff (1939) described *Phygoxerotes*, he referred the genus to the "Sphaerotrichopidae" (= Dalodesmidae), apparently on negative grounds only. He noted that the genus could not be referred satisfactorily to any of the other South African polydesmid families, but at the same time pointed out a resemblance between the gonopods of *Phygoxerotes* and certain Gomphodesmidae and Platyrhacidae, and suggested a close relationship between these two families and the "Sphaerotrichopidae".

Verhoeff (1940) described the genus *Vaalogonopus* and erected for this genus and *Phygoxerotes* the family "Vaalogonopidae" (= Vaalogonopodidae). The two genera are very closely related indeed, but *Vaalogonopus* lacks the enlarged paranota of the second somite, and its collum is particularly enlarged. Obviously, it was under the impression of the latter feature that Verhoeff dropped his former opinion on the relationship of *Phygoxerotes* and associated the Vaalogonopodidae with other polydesmid groups having an enlarged collum: the Cryptodesmidae (in a wide sence, including the Pyrgodesmidae of Hoffman's classification), the Niponiellidae (now regarded a tribe in the family Cryptodesmidae), and the Macellolophidae (now a tribe in the chelodesmoid family Xystodesmidae according to Hoffman). It is a point of interest to mention here that Verhoeff, quite incidentally, pointed to a certain resemblance in the gonopods of the Vaalogonopodidae and the genus *Gonomastis* Attems (= *Helodesmus* Cook).

Lawrence (1953), commenting on the taxonomic status of *Phygoxerotes*, but apparently ignorant of Verhoeff's paper on *Vaalogonopus*, rejected the opinion that the genus is related to the "Sphaerotrichopidae" or the Gomphodesmidae. He pointed out that there are many instances of superficial similarity in the gonopods of genera belonging to quite unrelated families. Lawrence drew attention to a certain overall similarity between *Phygoxerotes* and *Prosopodesmus* Silvestri, but otherwise seemed to regard *Phygoxerotes* as a diminutive type of Platyrhacidae.

Recently, Hoffman (1980) placed the Vaalogonopodidae with the Dalodesmidae into his suborder Dalodesmidea, a taxon equivalent to the suborders Chelodesmidea, Paradoxosomatidea and Polydesmidea.

In the present understanding of the classification of the order Polydesmida the relationship between the Vaalogonopodidae, Platyrhacidae, Gomphodesmidae or "Macellolophidae" as suggested by Verhoeff and Lawrence, can be ruled out without further comment. In fact, there are only two options to be considered. Either the Vaalogonopodidae, mainly on account of the characters of the gonopods, is to be associated with the Dalodesmidae, or, if a number of external particulars are given preference, it should be related to certain families in the suborder Polydesmidea.

Actually, the first option was followed by Hoffman, who, by assigning only the Vaalogonopodidae and the Dalodesmidae to the suborder Dalodesmidea, laid special emphasis on the relationship between the two families.

However, as was pointed out above in connection with the status of *Asphalidesmus* and *Atopodesmus* the strong evidence of the non-gonopod characters of the Vaalogonopodidae opposes such a close association with the Dalodesmidae. The male leg setation, the structure of the second somite and the sculpture of the metatergites, in combination, seem to provide sufficient argument in favour of the second option.

A family in the suborder Polydesmidea of particular importance to the taxonomic position of the Vaalogonopodidae appears to be the Haplodesmidae. This group has been recently reinstated almost simultaneously by Hoffman (1980) and Jeekel (1980), although based on different concepts. Jeekel included only *Cylindrodesmus* Pocock (with *Fijiodesmus* Chamberlin as a probable additional synonymy) and, with some reservation, *Phlyctodesmus* Chamberlin. Hoffman adopted a wider concept and included also *Helodesmus* Cook (with its synonyms *Gonomastis* Attems and *Porauxus* Chamberlin) and *Prosopodesmus* Silvestri, each representing a different subfamily.

The association of *Helodesmus* and *Prosopodesmus* with *Cylindrodesmus* was a daring step but seems quite correct. Some doubt might be expressed about the necessity to refer each to a separate subfamily. The concept of the Haplodesmidae was apparently mainly based on the agreement of the pertinent genera in the structure of the second somite, and the fact that the gonopod characters did not contradict their association.

For similar reasons it seems quite likely indeed that the Vaalogonopodidae should be combined with the Haplodesmidae at a subfamily level within the latter. It is of historic interest but only of minor importance that the coordination of the two taxa agrees with the gratuitous remarks on the relationship of the South African Vaalogonopodidae and *Gonomastis* and *Prosopodesmus* by Verhoeff and Lawrence.

In connection with this discussion the status of another enigmatic polydesmoid genus should be considered. *Atopogonus* [*sic!*] Carl, 1926, is based on a single species from New Caledonia, which like the Haplodesmidae is characterized by the collar-like structure of the second somite. Its metatergites are covered by numerous setiferous granules and Carl characterized the general habit as "*Cylindrodesmusartig*". On the other hand, the gonopods have a peculiar structure and lack the coxal horn. Obviously on this account Carl referred the genus to the Rhachodesmidae. Verhoeff (1941) erected the family Atopogonidae for the genus, but still associated it with the Rhachodesmidae. It is quite clear that *Atopogonus* has nothing to do with the Rhachodesmidae, and that the loss of the coxal horn in the genus is the result of an entirely independent evolutionary process. Hoffman (1980) quite correctly removed the Atopogonidae from its association with the Rhachodesmidae but had to place the genus and family among those polydesmid taxa with uncertain status.

It seems best that the Atopogonidae, like the Vaalogonopodidae, be a taxon subordinate to the Haplodesmidae.

The following preliminary classification summarizes the above discussion. To avoid a too complex picture and in accordance with Hoffman's classification, the previous family names are given the rank of subfamily. It will be clear that numerous changes in the position of the genera may occur when Hoffman's prediction that "I do not doubt that its [the Haplodesmidae] ranks will be enlarged as material of various poorly-known small polydesmoids is available for study", is substantiated.

Family Haplodesmidae
Subfamily Haplodesminae (*Cylindrodesmus* Pocock)
Subfamily Helodesminae (*Helodesmus* Cook)
Subfamily Prosopodesminae (*Prosopodesmus* Silvestri)
Subfamily Vaalogonopodinae (*Vaalogonopus* Verhoeff, *Phygoxerotes* Verhoeff)
Subfamily Atopogoninae (*Atopogonus* Carl)
Status uncertain: *Atopodesmus* Chamberlin, *Phymatodesmus* De Saussure & Zehntner, *Phlyctodesmus* Chamberlin.

Whether or not the genus *Rhipidopeltis* Miyosi belongs to the Haplodesmidae seems uncertain. Perhaps it would be better to associate this genus with the family Cryptodesmidae.

That the Haplodesmidae have a certain relationship with the Doratodesmidae, as suggested in Hoffman's classification seems quite likely. In fact, one may wonder if not certain genera referred to the Doratodesmidae should not be reallocated in the Haplodesmidae.

KEY TO THE GENERA OF THE ORDER POLYDESMIDA REPORTED FROM TASMANIA (EXCLUDING INTRODUCED EUROPEAN SPECIES)

1a Coxae of gonopods free, not coalesced medially; the gonopod aperture medially more or less constricted. Legs of male generally with tibial and tarsal scopulae, the basal podomeres without modified setae. Paranota with swollen lateral margins, which are dorsally demarcated by a furrow and ventrally by a depression. The pores situated on the lateral surface of the paranota. When paranota are absent the pores open on the lateral side of the metatergites and are not accompanied by furrows. Metatergites usually hairless, generally with a transverse furrow, but without other sculpture. (Paradoxosomatidae) ..... *Notodesmus* Chamberlin

1b Coxae of gonopods medially solidly connected; the gonopod aperture elliptical, oval or heart-shaped, not medially constricted. Legs of male without scopulae, either with unmodified setae or with all podomeres with short, dense setation of modified setae. Paranota without swollen lateral margins, only dorsally demarcated by a premarginal furrow. Pore situated on the laterodorsal side, in or near the premarginal furrow. Metatergites either without transverse furrow or sculpture, or with areas demarcated by furrows, or densely covered by setiferous granules. 2

2a Second somite much wider than collum; its paranota anteriorly and posteriorly expanded, directed downward so as to more or less embrace the head and collum like a collar. Metatergites with numerous small setiferous granules. Legs of male without modified setae. Small species of about 6 mm length. (Haplodesmidae) ..... *Asphalidesmus* Silvestri
..... *Atopodesmus* Chamberlin

2b Second somite not much wider than collum; its paranota not differing essentially from those of the next somites. Metatergites either smooth and without sculpture or with a transverse furrow and a number of inflated areas marked by sulci. Legs of male ventrally with a dense setation of short stiff bristles and spherical bristles. Larger species of over 10 mm length. (Dalodesmidae) 3

3a Somites cylindrical, weakly constricted in the waist area. Paranota reduced, ridgelike ..... *Gasterogramma* Jeekel

3b Somites with well developed paranota. Metatergites dorsally more or less flattened 4

4a Nineteen somites. Metatergites with a transverse furrow and with 4 to 6 weakly demarcated areas in front ..... *Tasmaniosoma* Verhoeff

4b Twenty somites. Metatergites without transverse furrow or demarcated areas 5

5a Metatergites with three transverse rows of setae. Each tarsus exceeding each other podomere in length, widely curved. ..... *Tasmanodesmus* Chamberlin

5b Metatergites without transverse rows of setae, only with a long hair mesad of caudal edge of paranota. Each tarsus not (much) longer than femur, not curved. ..... *Lissodesmus* Chamberlin

LISSODESMUS CHAMBERLIN

Lissodesmus Chamberlin, 1920, p.135.
Australopeltis (as subgenus of *Pseudoprionopeltis* Carl, 1902) Johns 1964, p.47; (as genus) Hoffman, 1980, p.184.

Type-species

Lissodesmus modestus Chamberlin, 1920 (type-species of *Australopeltis: Pseudoprionopeltis martini* Carl, 1902).

Remarks

To this monotypic genus are now added four new vicariant species from Tasmania, and *Lissodesmus martini* (Carl) from Victoria.

As in many dalodesmid genera, the gonopods in *Lissodesmus* are of a highly modified type in comparison with the more primitive gonopods found in certain paradoxosomatid genera. There are no indications of an articular subdivision in the telopodite and the location and size of the various branches deviate greatly from the presumed precursor.

In essence, the telopodite of the gonopods in *Lissodesmus* gives rise to four separate elements, one of which contains the spermal channel and must be regarded as the solenomerite. This is a relatively small, spine-like process, apically acuminate and generally bearing one or two minute preapical lappets. Its base is situated about halfway the total length of the telopodite or a little more proximally, either on the medio- or the latero-anterior side.

Mediocaudad of the solenomerite base there arises a small spine, or truncate spine or lanceolate process, which, consistent with the morphological interpretation of the paradoxosomatid gonopods (cf. Jeekel 1968, p.21, fig.1), is considered to be the homologue of the tibiotarsus.

A third process, bifurcate in the newly described Tasmanian species but unbranched in *L. modestus* and *L. martini*, arises laterocaudad of the solenomerite base, and for that reason may be considered to be a process either of the femur or postfemur of the telopodite.

The main body of the telopodite is, however, formed by a strongly elongate prefemur, the homology being substantiated by the fact that at least in *L. adrianae* n.sp. its caudal surface is continuously setiferous up to near the apex and that it does not show any discontinuity in its chitinous structure.

According to the above homologization, it is concluded that the femur and postfemur of the gonopods in *Lissodesmus* are vestigial and have merged into the prefemur. A similar situation has been described for *Gasterogramma* Jeekel (1982, p.10). The latter genus is moreover characterized by a strong torsion of the telopodite.

In conformity with the original diagnosis of the genus all species treated here have a body of a head and 20 somites. The poreformula is usually normal, but one new species, *L. perporosus*, has an abnormal formula: 5, 7, 9 - 19. This condition would formerly have been considered sufficient basis for a separate genus. But the great similarity in the gonopod structure of this species and the other Tasmanian species devaluates this character to the level of specific importance only.

In the polydesmid fauna of Tasmania the representatives of the genus are easily distinguished by their pallid colour, smooth metatergites and lack of any furrows or granulation, one long hair arising from the caudal border of the paranota just mesad of the latero-caudal edge, and the typical structure of the gonopods.

Key to the Species of *Lissodesmus*

1a Posterior margin of paranota with about three triangular teeth. Gonopods in situ reaching to just in front of the 6th sternite. Femoral process of gonopods unbranched, not reaching the apex of the prefemur, its apex acuminate, entire. Prefemur with a single median uncate process. Width of male 2.0 mm (Victoria). ..... *L. martini* (Carl)

1b Posterior margin of paranota without teeth. Femoral process of gonopods bifurcate and not reaching the apex of the prefemur, or unbranched and reaching as far as the apex of the prefemur. (Tasmania) 2

2a Gonopods in situ reaching the anterior margin of the 5th sternite. Femoral process reaching as far as the apex of the prefemur, unbranched, its apex subspatulate, serrulate. Prefemur without medial uncus. Paranota with

distinctly notched lateral margins and acutely angular, well produced caudal edges. Width of male 2.0-2.3 mm ..... *L. modestus* Chamberlin

2b Gonopods in situ scarcely surpassing the anterior margin of the 6th sternite. Femoral process bifurcate. Lateral margins of paranota weakly notched; the caudal edges of the paranota only weakly produced 3

3a Pores on somites, 5, 7, 9 - 19. Tibiotarsus, solenomerite and femoral process arising well proximad of half the length of the telopodite of the gonopods. Prefemur with four medial unci. Width of male 2.4-2.7 mm ..... *L. perporosus* n.sp.

3b Pores on somites 5, 7, 9 -10, 12 - 13, 15 - 19. Tibiotarsus, solenomerite and femoral process arising from about the middle, or a little distad of the middle of the length of the telopodite of the gonopods 4

4a Femoral process arising well distad of the base of the tibiotarsus, one of its branches finely fringed. Anterior side of prefemur, proximad of base of solenoperite, convex. Prefemur with two preapical unci. Width of male 1.7-2.0 mm. ..... *L. margaretae* n.sp.

4b Femoral process and tibiotarsus arising from about the same level. Anterior side of prefemur straight. Both branches of the femoral process simply acuminate. 5

5a Branches of femoral process of the gonopods of subequal length. Tibiotarsus spiniform, acuminate. Prefemur setiferous up to half its length; its distal part bearing one medial uncus. Width of male 1.7-2.0 mm ..... *L. alisonae* n. sp.

5b Branches of femoral process quite unequal in length. Tibiotarsus truncate. Prefemur setiferous up to near the apex, serrulate, without unci. Width of male 2.5-2.8 mm. ..... *L. adrianae* n. sp.

Lissodesmus modestus Chamberlin

Lissodesmus modestus Chamberlin, 1920, p.135.

Previous record

Russell Falls, Tasmania.

Material

Sta.105. Mt Field National Park, 4 km W National Park, 9 km NNE Maydena, 27.XI.1980 [upper zone of temperate rainforest (*Nothofagus, Eucalyptus, Dicksonia*) along nature track, very wet soil, under logs], 1 ♂, 4 juv. ♀ (18 somites).

Sta.108. Mt Wellington, 7 km SW Hobart, 28.XI.1980 [wet sclerophyllous forest with some ferntrees, under logs, stones and litter], 2 ♂, 1 ♀, 1 juv. ♂ (19 somites), 1 juv. ♀ (19 somites).

Description

Colour.- Pale orange brown, the head and tergites with a fine network of reddish brown, the darker pigment concentrated particularly in a narrow zone along the posterior margin of the tergites. Venter, sternites and legs pale pinkish yellow.

Width.- ♂: 2.0-2.3 mm, ♀; 2.4 mm, juv. ♂ (19 s.): 2.1 mm, juv. ♀ (19 s.): 2.2 mm, juv. ♂ (18 s.): 1.4-1.5 mm.

Head and antennae.- Labrum rather widely and moderately deeply emarginate. Clypeus rather convex, smooth, well impressed towards the labrum. The lateral border straight, without a notch near the labrum. Pubescence moderately dense up to the middle of the vertex, and on the lateral parts of the head. The setae partly long; some hairs on the vertex quite long. Antennal sockets not impressed, separated from each other by two times the diameter of a socket or by 0.9 times the length of the 2nd antennomere. Postantennal groove wide and rather deep, the wall in front moderately prominent. Vertex smooth and shiny, transversely weakly and evenly convex, longitudinally rather convex, particularly in the upper half. Vertigial sulcus weakly impressed, disappearing well above the upper level of the antennal sockets. Antennae of moderate length, moderately stout, a little clavate,

with the 6th antennomere thickest. Antennomeres 2 and 3 subcylindrical, widening distad, the 4th and 5th obconical, the 6th subcylindrical, a little inflated. Relative length of antennomeres 2 to 6: 1.00, 0.90, 0.65, 0.65, 0.85 (6th to 8th inclusive: 1.20). Pubescence moderate in proximal antennomeres, becoming dense in the distal ones.

Collum.- A little wider than the head, subtrapezoidal in dorsal outline. Anterior margin straight or faintly convex in the middle, laterally rather strongly rounded, and straight again towards the lateral edge. Posterior margin weakly concave in the middle, laterally widely rounded and straight again towards the edge. Lateral margin with two weak indentations (both sometimes bearing a rather long seta); the posterior edge subangular, wide, very narrowly rounded and not produced caudad. Surface smooth, with a transverse row of rather long setae along the anterior margin. A long hair also near the posterior margin, rather close to the lateral edge. Surface transversely and longitudinally widely and evenly convex. Lateral margin with a fine rim, the premarginal furrow sharply impressed, disappearing near the lateral edge of the vertex.

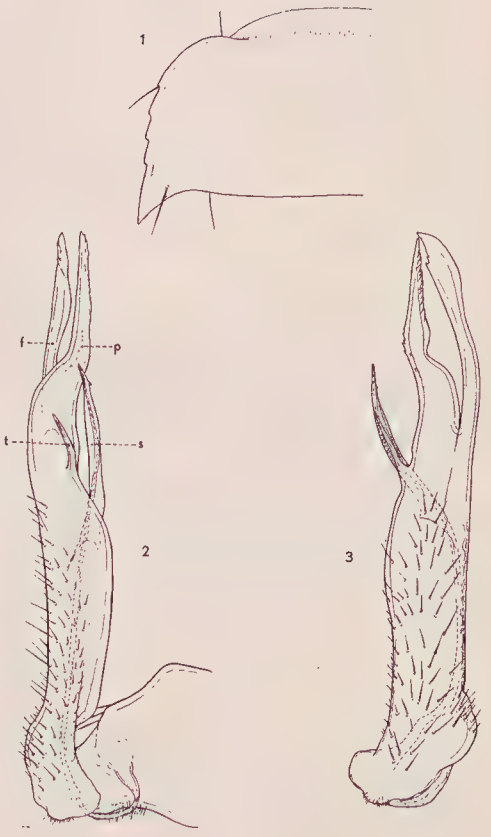
Somites.- Constriction rather weak. Waist broad, sharply demarcated from the prosomites, not distinctly demarcated from the metatergites, the transition to metatergites finely longitudinally striate. Prosomites a little dullish. Surface of metatergites more shiny, hairless except for a long seta quite near the concave posterior margin of the paranota. No transverse furrow or other sculpture, at most a vague transverse depression. Sides somewhat rugulose or subgranulose. No pleural keels.

Paranota.- Second somite somewhat wider than the collum; the 3rd scarcely wider than the 2nd, and the 4th more distinctly wider than the 3rd. Paranota of 2nd somite in dorsal aspect with the anterior margin a little shouldered at base, otherwise widely convex. The latero-anterior edge widely subangular, narrowly rounded, with a small but distinct lateral tooth bearing a long hair. Lateral margin widely and almost evenly rounded, with three abortive teeth. Posterior border widely concave; the lateroposterior edge angular, about 90° and scarcely produced caudad. In lateral aspect the paranota are scarcely sloping cephalad, with the upper margin widely and evenly concave. Marginal rim laterally slightly incrassate, sharply demarcated dorsally by a premarginal furrow running anteriorly to the waist and disappearing caudally near the posterior edge. Posterior margin with a sharp furrow from near the edge to the base of the paranotum. Paranota of 3rd somite similar to those of the 2nd. The lateroanterior edge not angular and without tooth, the anterior border merging into the lateral by a narrow rounding. Lateral border more weakly convex than in the 2nd somite, with three teeth, the anterior of which generally bears a long hair; the teeth more distinct than in the 2nd somite. Posterior edge more acutely angular than in the 2nd somite, pointed and produced a little caudad. Posterior border less widely concave than in the 2nd somite. Paranota of 4th somite similar to those of the 3rd, but the lateral border scarcely convex, almost straight. The lateroposterior edge more acuminate, and more produced caudad than in the 3rd somite, acutely angular. Posterior margin becoming more concave near lateral edge. Paranota of 3rd and 4th somites sloping a little cephalad in lateral aspect, and gradually less laterad from the 2nd to the 4th somite. Paranota of 5th and subsequent somites (fig. 1) with anterior margin shoulder a little at base up to the 18th somite, rather widely rounded and merging into the lateral margin which is almost straight and diverging a little in caudal direction. Four distinct, but not deeply incised lateral teeth, the first generally with a long hair. Posterior edges becoming more and more acute; acuminate and pointed especially in the posterior half of the body. Posterior margin concave, especially at the base. Upper surface of paranota slightly swollen. Pore formula normal, the pore small and inconspicuous, situated near the margin just behind the last lateral tooth, facing laterad, caudad and a little dorsad, just at the base of a weak and small swelling. Marginal rims distinct, the premarginal furrow disappearing at waist and near posterior edge, in poriferous somites just behind the pore. Premarginal furrow along posterior border disappearing near posterior edge near the seta, and at base of paranotum. The marginal rim a little thicker than in the other Tasmanian species. In lateral aspect the upper demarcation of the paranota is faintly concave, turning abruptly upwards anteriorly.

Sternites and legs.- Sternites of middle somites longer than wide (ratio 1.7:1.0). Cross impressions well developed, rather deep and furrow-like. Pubescence dense, but setae

short and not visible at low magnification. Sternite of 4th somite moderately wide, with a deep median furrow. Sternite of 5th somite with a deep median furrow between the anterior coxae, deeply and widely excavate between the posterior coxae. Sternite of 6th somite with a wide and deep excavation, the transverse impression distinct only between the subsequent coxal sockets. Sternite of 7th somite with a broad oval gonopod aperture, the margin caudally and especially laterally a little raised; the posterior part with a median furrow. Sternite of 8th somite not modified. Legs rather long, strongly incrassate, especially prefemur and femur. The prefemora dorsally globose, the femora dorsally convex, ventrally straight. Pubescence ventrally very dense, with stiff, short, crooked setae up to the postfemur, and globular setae on tibia and tarsus. Dorsal pubescence moderate in tarsus, sparse in tibia and postfemur, not visible at low magnification in the more basal podomeres. The setae rather short and straight. Legs of first and second pairs not particularly incrassate and relatively short. Coxa of 2nd legs medially widened and with a small distal cone tipped with some setae of moderate length. Relative length of podomeres 2 to 6: 0.90, 1.00, 0.45, 0.40, 1.00; the claw rather long.

Anal somite.- Dorsal profile weakly convex. Sides of epiproct concavely converging, nearly parallel towards the apex. Epiproct rather narrow, moderately thick dorsoventrally and rather long; the apex narrowly emarginate, with two short paramedian cones. Anal ring moderately setiferous with conspicuous long setae on minute granules. Paraprocts with rather wide and moderately high marginal rims; the setae not on granules. Hypoproct subtriangular, with sides concave at base, the apex rounded; setae not on granules.



FIGS 1-3 *Lissodesmus modestus* Chamberlin, 1920, ♂ from Sta.108. 1 - left side of 11th somite, dorsal aspect. 2 - right gonopod, medial aspect. 3 - telopodite of left gonopod, caudal aspect. [f - femoral process; p - prefemoral process; s - solenomerite; t - tibiotarsus].

Gonopods (figs 2-3).- Coxa broad at base and solidly connected with the coxa of the opposite gonopod. Its distal part narrowing, with a few long setae on the anterior side, and an area with short setae on the caudal side. Telopodite very long, in situ reaching the anterior margin of the sternite of the 5th somite. Prefemur setiferous up to about half the length of the telopodite, distally produced into a slender process which shows a slight crook towards the apex. Apex itself with serrate margins, tapering. Solenomerite arising just proximad of half the length of the telopodite, reaching to three-quarters of that length. Tibiotarsus arising from the medial side of the telopodite, short, spiniform. Femoral process arising from the lateral side of the telopodite at about two-thirds of the length of the telopodite, slender in most of its length and distally widening a little. The femoral process reaches as far distad as the prefemur.

Female.- A little more robust than the male, but otherwise quite similar. Antennal sockets separated by 2.5 times the diameter of a socket or by 0.9 times the length of the

2nd antennomere. Relative length of antennomeres 2 to 6: 1.00, 0.80, 0.60, 0.65, 0.85 (6th to 8th inclusive: 1.20). Sides of somites up to about the 4th a little granulose. Sternites longer than wide (ratio 1.35:1.00). The pubescence of the sternites rather dense, with setae of moderate length. Legs a little shorter than in the male and not incrassate. The prefemur thick and dorsally widely convex, the femur much narrower than in the male. Relative length of podomeres 2 to 6: 1.00, 1.00, 0.40, 0.40, 0.90. Ventral pubescence of podomeres rather dense, with setae of moderate length. The typical modified setation of the male is lacking. Upper side of podomeres sparsely setiferous, moderately in tibiae and tarsi. Epigynal structure consisting of a transverse plate, directed ventrad and shielding the coxae of the 2nd pair of legs from behind. The plate is broadly triangular, with a wide median narrowly rounded edge, the sides widely and weakly emarginate, with laterally a small slight elevation. Coxae of 2nd legs broad, their caudal side with a small, slightly swollen subquadrate process projecting caudad.

Remarks

Lissodesmus modestus is distinguished from all other known species of the genus by the remarkable length of the telopodite of the gonopod, which, in situ, reaches as far as the anterior border of the sternite of the 5th somite. Also characteristic are the length of the femoral process, which reaches as far distal as the apex of the prefemur, the distinct teeth of the lateral margin and pronounced posterior edges of the paranota. *L. modestus* differs from the Tasmanian species in that the femoral process is unbranched; a character shared with the Victorian *L. martini* (Carl).

In his description Chamberlin stated that the 2nd and 6th antennomeres are the longest with which present observations do not agree. It seems possible that Chamberlin actually meant the length of the 2nd and 6th to 8th antennomeres. Otherwise, considering the fact that the material from Sta.105 is almost topotypical and that Chamberlin's description of the genus and species matches the specimens at hand in other details, there can be hardly any doubt about the correctness of the identification.

Lissodesmus adrianae n.sp.

Material

Sta.96. Ben Lomond National Park, 35 km ENE Evandale, 23.XI.1980 [along the road to the top of Ben Lomond, near the park ranger office, wet sclerophyllous forest with dense undergrowth of shrubs, under logs, litter and in humus]. ♂ holotype, 9 ♂, 19 ♀, 10 juv. ♂ (19 somites), 9 juv. ♀ (19 somites), 2 juv. ♀ (18 somites) paratypes.

Sta.97. 10 km NE Blessington, 28 km ENE Evandale, 23.XI.1980 [dry type *Eucalyptus* forest in grassland, under logs]. 1 ♀ paratype.

Description

Colour.- In general greyish orange brown, the venter, sternites and legs somewhat paler.

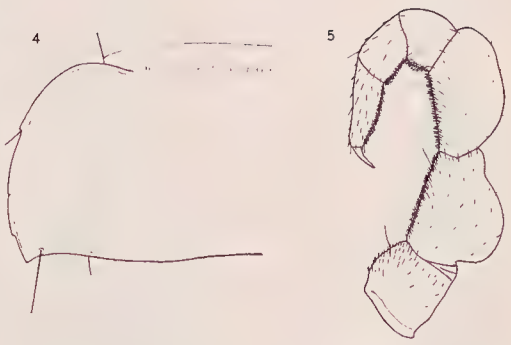
Width.- ♂: 2.5-2.8 mm, ♀: 2.7-3.2 mm, juv. ♂ (19 s.): 2.0-2.1 mm, juv. ♀ (19 s.): 2.0-2.4 mm, juv. ♀ (18 s.): 1.6-1.8 mm.

Head and antennae.- Labrum weakly and moderately widely emarginate. Clypeus strongly impressed towards the labrum; its lateral border a little emarginate near the labrum. Pubescence of headplate becoming rather sparse in the frontal region and in the lower part of the vertex. Antennal sockets somewhat impressed. Postantennal groove wide and shallow, the wall in front very weakly prominent. Vertex longitudinally rather strongly and evenly convex. Antennae shortish and moderately stout, distinctly clavate, with the antennomeres 2 to 6 each a little wider than the preceding. Relative length of antennomeres 2 to 6: 1.00, 0.85, 0.60, 0.60, 0.65 (6th to 8th inclusive: 0.90).

Collum.- Lateral margin widely rounded, with three weak indentations, and caudally subangular, narrowly rounded. Surface with, besides the series of long setae along the anterior margin, some more setae just in front of the middle.

Somites.- Sides smooth.

Paranota.- Second and 3rd somites each a little wider than the preceding somite, the 4th scarcely wider than the 3rd. Paranota of 2nd somite in dorsal aspect with the anterior margin shouldered, but otherwise straight. Lateral margin a little more convex towards the lateroposterior edge, with three minor or partly abortive teeth. Posterior border faintly concave. The lateroposterior edge widely angular. In lateral aspect the upper margin of the paranota is straight or faintly concave, concavity upwards, and more strongly concave near caudal edge. Marginal rim thin and narrow. Paranota of 3rd somite with the anterior border rounded, the lateroanterior edge less pronounced than in the 2nd somite. Paranota of 4th somite similar, but without lateroanterior edge, the anterior margin merging into the lateral margin. Paranota of 5th and subsequent somites (fig. 4) with the anterior margin shouldered at base except in the 17th to 19th somites. Lateral margin widely and almost evenly convex, diverging slightly caudad, curving mesad a little towards the caudal edge. Margin with three or four weak teeth, of which the first and last are the most distinct, the first often bearing a rather long hair. Poriferous somites with the lateral margin a little more strongly incurved from the pore area onwards. Posterior edges about rectangular, pointed, becoming more acuminate in the second half of the body. Pores situated near the caudal edge, just a little behind the second lateral marginal tooth. Pores facing laterad, dorsad and a little caudad. In lateral aspect the dorsal demarcation of the paranota is faintly concave, more so near the caudal edge, and particularly in the poriferous somites curving rather strongly upward near the pore.



FIGS 4-5 *Lissodesmus adrianae* n.sp., ♂ paratype. 4 - left side of 11th somite, dorsal aspect. 5 - leg of 7th somite.

Sternites and legs.- Sternites of middle somites longer than wide (ratio 1.3:1.0). Cross impressions medially and transversely with a fine central furrow. Sternite of 5th somite lacking the modifications of the previous species. Legs (fig. 5) with the femora ventrally quite faintly arched. Coxae of 2nd pair medially produced into a low rounded cone bearing an apical tuft of setae. Relative length of podomeres 2 to 6: 0.90, 1.00, 0.50, 0.45, 0.75.

Anal somite.- Upper profile straight or faintly convex. Epiproct moderately wide. Sides of epiproct not nearly parallel towards the apex. Apex with a pair of rather long and slender terminal cones, with a deep emargination in between. Hypoproct rather long, narrowly trapezoidal, with the sides straight at base and faintly convex distally; the posterior margin almost semicircularly rounded.

Gonopods (figs 6-7).- Telopodite in situ just reaching the posterior coxae of the 5th somite. Prefemur setiferous up to near the apex of the telopodite; the apex of the prefemoral process truncate-serrulate, medial margin also serrulate. Solenomerite arising about halfway the length of the telopodite, and reaching to about two-thirds of length. Tibiotarsus short, distally truncate, arising a little distad of base of solenomerite. Femoral process arising from about the same level as the tibiotarsus or solenomerite, bifurcate; the posterior branch short, pointing caudad and a little distad; the distal branch longer, reaching to about three-quarters of the length of the telopodite.

Female.- Antennal sockets separated by 2.25 times the diameter of a socket or by 1.2 times the length of the 2nd antennomere. Relative length of antennomeres 2 to 6: 1.00, 0.80, 0.70, 0.60, 0.75 (6th to 8th inclusive: 1.00). Sternites longer than wide (ratio 1.2:1.0). Relative length of podomeres 2 to 6: 1.00, 0.90, 0.40, 0.40, 0.75. The epigynal structure with the plate a little lower than in the previous species, the lateral edges laterad of emarginations not apparent. Coxae of 2nd pair of legs broad, but without posterior projection.

FIGS 6-7 *Lissodesmus adrianae* n.sp. ♂ holotype. 6 - right gonopod, medial aspect. 7 - telopodite of left gonopod, caudal aspect. Lettering as in figs 1-3.

Remarks

In the points not mentioned the description of *L. modestus* applies.

L. adrianae n.sp. approaches *L. perporosus* n.sp. in its relatively large size and also in the outline of the paranota. It is easily distinguished by the normal poreformula and the structure of the gonopods.

The species is dedicated to Mrs Adriana M. Jeekel-Rijvers, who actively participated in obtaining the type material.

Lissodesmus alisonae n.sp.

Material

Sta.99. 8 km NW Frankford, 15 km SW Beaconsfield, 24.XI.1980 [open *Eucalyptus* forest with grassland, rather wet, under logs and in soil]. ♂ holotype, 12 ♂, 21 ♀, 1 juv. ♂ (19 somites), 1 juv. ♀ (18 somites) paratypes.

Description

Colour.- In general light orange brown. Head with frons and lower part of vertex reddish brown, areolated with the lighter colour. Antennae with the distal part of the 4th, and the entire 5th, 6th and 7th antennomeres reddish brown. The anterior, lateral and posterior margins of the collum, and the posterior margin of the metatergites, broadest medially, also reddish brown, areolated with light colour. Venter, sternites and legs and anal somites light orange brown.

Width.- ♂: 1.7-2.0 mm, ♀: 2.0-2.3 mm, juv. ♂ (19 s.): 1.6 mm, juv. ♀ (18 s.): 1.4 mm.

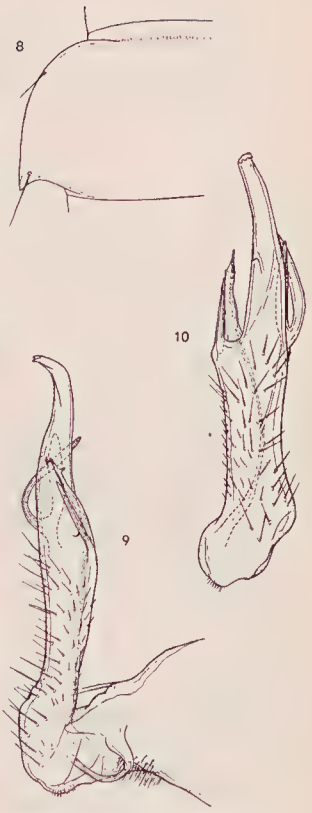
Head and antennae.- Clypeus with minute wrinkles; its lateral border straight, weakly emarginate towards the labrum. Antennal sockets a little impressed at the oral side; separated in 2.1 times the diameter of a socket or by the length of the 2nd antennomere. The 6th antennomere subcylindrical, with sides a little convex, the base constricted. Relative length of antennomeres 2 to 6: 0.95, 0.95, 0.75, 0.75, 1.00 (6th to 8th inclusive: 1.20).

Collum.- Scarcely wider than the head. The anterior border almost straight in the middle, gradually more convex towards the lateral side, the lateral border almost evenly convex, scarcely undulate. Posterior border emarginate in the middle, straight more laterally and faintly convex near lateroposterior edge. The lateroposterior edge about rectangular, narrowly rounded, not produced caudad. Behind the series of setae along the anterior margin a few long setae; the long hair near the posterior margin somewhat remote from the lateroposterior edge. Premarginal furrow along the lateral border continuous with the furrow along the posterior margin.

Paranota.- Fourth somite a little wider than the 3rd. Paranota of 2nd somite with the anterior edge subangular, rather narrowly rounded and with a small but distinct tooth. Lateral border with three teeth, of which the anterior is distinct and the posterior almost abortive. Posterior border faintly concave. The lateroposterior edge a little over 90°, acuminately angular, not produced caudad. Marginal rim thin, the premarginal furrow of lateral border merging into that of the posterior border. In lateral aspect the paranota are sloping a little cephalad. Paranota of 3rd somite with the lateral border a little more convex than in the 2nd somite. Lateroanterior tooth small and indistinct, the lateral

two or three teeth similar to those of 2nd somite. Posterior border distinctly emarginate near the lateroposterior edge which is acutely angular, pointed and a little produced caudad. Paranota of 4th somite with the lateroanterior edge more widely rounded, merging into the lateral border. The lateral border a little more widely convex than in the 3rd somite, with three teeth which are weaker than in the 3rd somite, the anterior one bearing a hair. Posterior border more distinctly emarginate near lateral edge; the edge more acuminate and a little more produced caudad. Paranota of 5th and subsequent somites (fig. 8) shouldered a little at anterior base, though scarcely or not in the paranota of the second half of the body. Anterior and lateral borders widely rounded, the lateral border a little less convex, in general diverging a little caudad up to near the pore and behind the pore curving a little inwards. Lateral border without teeth; only in the 5th and a few subsequent somites a weakly indicated tooth with a seta. Posterior margin rather concave near the lateroposterior edge. Lateroposterior edge acute, finely pointed, a little produced caudad, projecting slightly caudad of posterior margin of somite in the caudal half of the body. Marginal rim narrow, present on all margins of the paranota. Pores facing laterad and a little caudad, scarcely dorsad. In lateral aspect the dorsal margin of the paranota is widely concave, concavity upwards, turning a little more strongly upwards near the posterior edge.

Sternites and legs.- Sternites of middle somites longer than wide (ratio (1.5:1.0). Sternite of 4th somite with a moderately deep median furrow. Sternite of 7th somite with posterior part widely concave. Legs with the femora faintly arched; the tibiae ventrally a little inflated towards the apex. Relative length of podomeres 2 to 6: 0.80, 1.00, 0.40, 0.50, 0.85.



FIGS 8-10 *Lissodesmus alisonae* n.sp. 8 - left side of 11th somite of ♂ paratype, dorsal aspect. 9 - right gonopod of ♂ holotype, medial aspect. 10 - telopodite of left gonopod of same, caudal aspect.

Anal somite.- Hypoproct truncate triangular; the apex rather widely rounded; the setae on weak tubercles forming the edges of the posterior margin.

Gonopods (figs 9-10).- Telopodite in situ reaching to just in front of the 6th sternite. Prefemur hairless in the distal two-fifths of its length, bearing only a single uncus at about three-quarters of length; the apex finely denticulate, curving a little mesocaudad. Solenomerite arising just distad of middle of length of telopodite, reaching to about three-quarters of length. Tibiotarsus a little shorter than the solenomerite, slender, straight, apically acuminate, arising just proximad of base of solenomerite. Femoral process arising from about the same level as the solenomerite, its anterior branch longer than its distal branch. The anterior branch curving distad and even a little cephalad.

Female.- Antennal sockets separated by 2.1 times the diameter of a socket or by 0.95 times the length of the 2nd antennomere. Relative length of antennomeres 2 to 6: 0.95, 0.80, 0.65, 0.60, 1.00 (6th to 8th inclusive: 1.20). Sternites 1.35 times longer than wide. Relative length of podomeres 2 to 6: 1.00, 0.95, 0.35, 0.40, 0.95. Epigyne with the triangular plate without distinct lateral edges. The coxae of the 2nd pair of legs medially extended, contiguous at base, obliquely truncate in distal half, without processes.

Remarks

In the points not mentioned the description of *Lissodesmus modestus* applies.

Together with *L. margaretae* n.sp. this is the smallest species of the genus. It is well characterized by the structure of the gonopods. In the paranota the wide curve of the anterior and lateral borders and the absence of distinct lateral teeth is characteristic.

The species is kindly dedicated to Miss Alison J.A. Green, the diligent Curator of Invertebrate Zoology at the Tasmanian Museum and Art Gallery.

Lissodesmus perporosus n.sp.

Material

Sta.100. Hellyer Gorge, 32 km SSW Somerset, 25.XI.1980 [temperate rainforest (*Nothofagus, Eucalyptus, Dicksonia*) along the Hellyer River, under logs], ♂ holotype, 6 ♂, 13 ♀, 3 juv. ♂ (19 somites), 2 juv. ♀ (19 somites) paratypes.

Sta.103. 12 km SW Derwent Bridge, 26.XI.1980 [open, recently burned *Eucalyptus* forest, rather wet, under logs], 1 ♂ paratype.

Sta.104. Lake St Clair National Park, near Cynthia Bay, 5 km WNW Derwent Bridge [wet *Eucalyptus* forest, under logs], 2 ♂, 4 ♀ paratypes.

Description

Colour.- In general similar to that of the preceding species. There is a fine network of reddish brown pigment, concentrated in particular along the anterior and lateral borders of the collum, along the posterior margin of the metatergites and on each laterodorsal side of the free part of the prosomites.

Width.- ♂: 2.4-2.7 mm, ♀: 2.9-3.3 mm, juv. ♂ (19 s.): 2.1-2.2 mm, juv. ♀ (19 s.): 2.2-2.3 mm. The material from Sta.100 is slightly larger in width than that of the two other stations.

Head and antennae.- Lateral border of clypeus faintly convex, weakly emarginate near the labrum. Clypeus finely rugulose. Antennal sockets anteriorly a little impressed, separated by 2.2 times the diameter of a socket or by the length of the 2nd antennomere. Relative length of antennomeres 2 to 6: 1.00, 1.00, 0.65, 0.65, 0.85 (6th to 8th inclusive: 1.10).

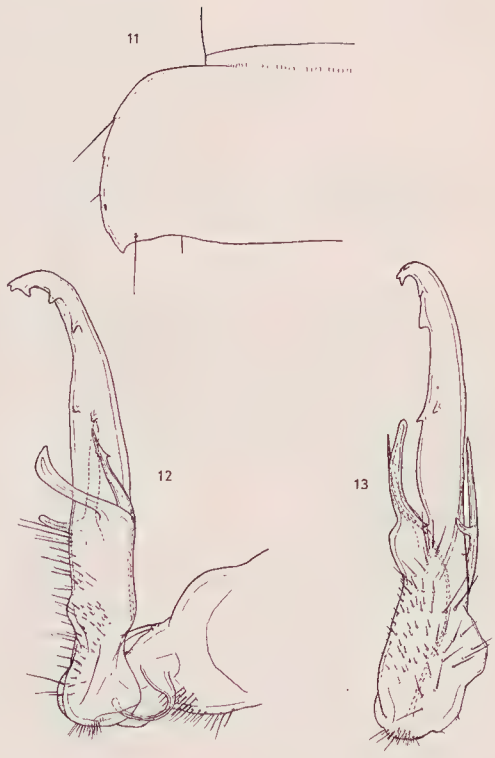
Collum.- Anterior border faintly convex, gradually a little more convex towards the sides; the lateral border weakly convex with three weak undulations. Posterior margin well emarginate in the middle, widely rounded more laterally, and straight or faintly concave towards the lateroposterior edge. Lateroposterior edge subangular, about 90°, narrowly rounded. Surface with behind the series of setae along the anterior margin a few long hairs. Marginal rim along the lateral border narrow; no premarginal furrow along the posterior margin.

Paranota.- Lateral margin in 2nd somite with three rather distinct teeth. Posterior margin faintly emarginate towards the lateroposterior edge, almost straight. The edge angular, a little wider than 90°, not or scarcely produced. Marginal rim along the lateral border narrow; no premarginal furrow along the posterior border. Paranota of 3rd somite with the lateroanterior edge marked by a minute tooth. The lateral margin with three rather distinct teeth, the anterior one bearing a hair. Lateral margin a little more convex than in the 2nd somite. Posterior margin a little more concave, especially near the posterior edge which is acuminately angular and about 90°. Paranota of 4th somite with the lateral margin as convex as in the 3rd somite. The posterior edge scarcely more defined than in the 3rd somite, slightly more produced caudad. Paranota of 5th and subsequent somites (fig. 11) shouldered a little at the anterior base up to the middle of the body. Anterior margin weakly rounded, becoming more convex laterally where it merges into the widely convex lateral margin. Lateral margin scarcely diverging caudad, posteriorly incurved behind the pore area. Lateral margin with four small but rather distinct teeth, the first of which generally bears a long hair. Posterior margin concave at base of paranota, then weakly convex and finally rather concave near the lateroposterior edge. Lateroposterior edge acutely angular, pointed, produced, especially in posterior half of body and projecting a little behind the margin of the somite in the posterior somites. Marginal rim narrow, no premarginal furrow along the caudal border. Poreformula abnormal: 5, 7, 9-19. The pores situated a little behind the third tooth. Pores facing laterad and caudad and a little dorsad.

Sternites and legs.- Sternites of middle somites longer than wide (ratio 1.2:1.0). Sternite of 7th somite in the posterior part rather widely medially excavate. Tibiae with a ventrodistal swelling. Relative length of podomeres 2 to 6: 0.90, 1.00, 0.45, 0.40, 0.95.

Anal somite.- Hypoproct truncate triangular; the apex faintly convex, the setae on the edges of apex.

Gonopods (figs 12-13).- In situ, reaching almost to the posterior margin of the 5th sternite. Distal half of prefemur without setae. The prefemur with two small unci on the medial side at about two-thirds of length and three more near the apex, which is bifid and curving caudad and a little mesad. Solenomerite arising at about two-fifth of length of telopodite, reaching to about three-fifths of length. Tibiotarsus arising mesad of basis of solenomerite at about the same level, rather strongly developed, somewhat sigmoidally curved, apically acuminate. Femoral process arising a little proximad of bases of solenomerite and tibiotarsus, its distal branch reaching to about three-fifths of length of telopodite, the caudal branch shorter, pointing caudad.



FIGS 11-13 *Lissodesmus perporosus* n.sp. 11 - left side of 11th somite of ♂ paratype, dorsal aspect. 12 - right gonopod of ♂ holotype, medial aspect. 13 - telopodite of left gonopod of same, caudal aspect.

Female.- Antennal sockets separated by 2.15 times the diameter of a socket or by the length of the 2nd antennomere. Relative length of antennomeres 2 to 6: 1.00, 0.85, 0.65, 0.60, 0.70 (6th to 8th inclusive: 0.90). Sternites of middle somites as long as wide. Relative length of podomeres 2 to 6: 0.95, 1.00, 0.45, 0.35, 0.85. Epigyne with triangular plate without lateral projections. Coxae of 2nd pair of legs medially expanded and with a medioterminal low cone.

Remarks

In the points not mentioned the description of *Lissodesmus modestus* applies.

This species is easily recognized by the configuration of the gonopods, by the abnormal distribution of the pores, and by the absence of a premarginal furrow along the caudal margin of the paranota. In the outline of the paranota it comes closest to *L. adrianae* n.sp., but differs in the less curved anterior margin.

Lissodesmus margaretae n.sp.

Material

Lake Augusta, 25.IV.1979 [on cushion plant], Tasmanian Department of Agriculture 19A17, ♂ holotype, 6 ♂, 1 ♀ (fragm.), 2 juv. ♀ (19 somites), 1 juv. ♀ (18 somites) paratypes.

Description

Colour.- Pale brownish yellow (probably decoloured); the head, antennae, collum and anterior part of metatergites areolate with darker pigment.

Width.- ♂: 1.7-2.0 mm, ♀: 2.0 mm, juv. ♀ (19 s.): 1.5 mm, juv. ♀ (18 s.): 1.3 mm.

Head and antennae.- Clypeus moderately impressed towards the labrum; its lateral border straight, with a faintly indicated emargination towards the labrum. Antennal sockets weakly impressed at the anterior side, separated by 2.2 times the diameter of a socket or by 1.1 times the length of the 2nd antennomere. Relative length of antennomeres 2 to 6: 1.00, 1.00, 0.65, 0.70, 0.85 (6th to 8th inclusive: 1.05).

Collum.- A little narrower than the head, subsemicircular in dorsal outline. Anterior border widely convex, gradually little more convex towards the lateral sides, and laterally widely convex or almost straight. Posterior border scarcely emarginate towards the lateroposterior edge. Lateroposterior edge rather widely angular, subacuminate, not at all produced. Lateral border and laterocaudal border with a fine marginal rim, vaguely interrupted at lateroposterior edge. The lateral border with three small but distinct teeth. Surface with some long hairs caudad of the transverse series along the anterior margin. The long hair near the lateroposterior edge a little more remote from the lateral and caudal borders than in the other species.

Paranota.- Second somite with the lateroanterior edge widely subangular, rather narrowly rounded, marked by a small but distinct tooth. Lateral border with three small but distinct teeth, each of them often bearing a hair. Posterior border straight. Lateroposterior edge widely angular, acuminate, not at all produced caudad. Marginal rim narrow, the premarginal furrow of lateral border merging with the furrow of the posterior border. In lateral aspect the paranota of the 2nd somite are widely concave, concavity upwards. Paranota of 3rd somite with the anterior and lateral borders more narrowly rounded than in the 2nd somite. The lateroanterior edge almost absent; the anterior and lateral borders merging by a narrower rounding. Lateral border with three small but distinct teeth. Posterior border faintly emarginate. Lateroposterior edge a little less widely angular than in the 2nd somite, not produced caudad. Paranota of 4th somite with the anterior and lateral borders each a little less convex than in the 3rd somite. Posterior margin straight, the lateroposterior edge widely angular as in the 3rd somite but slightly produced caudad. Paranota of 5th and subsequent somites (fig. 14) with the anterior border rather narrowly rounded, shouldered a little at base up to about the 16th somite, and merging gradually in the lateral border which is quite weakly convex and diverges a little caudad. The marginal rim thin, with three small but distinct teeth. Posterior edges about rectangular becoming a little acutely angular towards the caudal end of the body. Posterior border faintly concave, more strongly emarginate quite near the lateroposterior edges. Lateroposterior edges weakly produced and scarcely projecting behind the margin of the somites, except in the 17th and 18th somites where they project a little behind the margin. Pores facing laterad and a little dorsad, scarcely caudad. Lateral and posterior premarginal furrows connected, but indistinctly so in the poriferous somites. In lateral aspect the upper margin of the somites is concave, especially near the posterior end of the poriferous paranota.

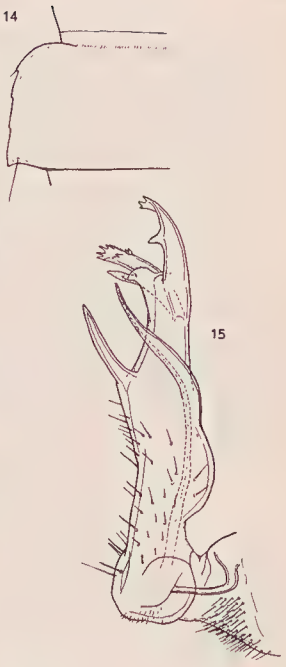
Sternites and legs.- Sternites of middle somites longer than wide (ratio 1.2:1.0). Sternite of 5th somite widely and rather deeply transversely concave in the caudal half. Sternite of the 7th somite with the lateral margin of the gonopod aperture rather strongly raised as a rounded lobe. Legs with the femora ventrally scarcely arched; the tibiae ventrodistally a little inflated. Prefemora and femora becoming gradually more slender caudad of 7th somite and almost not incrassate in the second half of the body. Relative length of podomeres 2 to 6: 0.85, 1.00, 0.30, 0.30, 0.95.

Anal somite.- Epiproct triangular, rather short, with the sides weakly concave, not parallel towards the end. Paraprocts with setae on weak tubercles. Hypoproct truncate triangular, the setae on the edges of the almost straight caudal margin.

Gonopods (fig. 15).- Telopodites in situ reaching a little in front of the 6th sternite, characterized by the branches diverging from the main axis instead of being more

or less parallel. Prefemur anteriorly a little swollen just distad of the base, setiferous up to half the total length of the telopodite. Prefemoral process bearing a large uncus halfway and a smaller one more distally; the apex trifid, curving a little caudad. Solenomerite arising about halfway the length of the telopodite, reaching to about four-fifths of length. Tibiotarsus spiniform, slenderly tipped, arising a little distad from the base of the solenomerite, and much more caudad than in the other species, reaching almost as far as the solenomerite. Femoral process arising from about three-quarters of the length of the telopodite, splitting into two branches: the distal branch apically fringed, the caudal branch smaller, acuminate, both curving a little caudad.

Female.- Antennal sockets separated by 2.35 times the diameter of a socket or by 1.2 times the length of the 2nd antennomere. Relative length of antennomeres 2 to 6: 1.00, 0.85, 0.70, 0.65, 0.90 (6th to 8th inclusive: 1.15). Sides of anterior somites not notably granular. Sternites of middle somites longer than wide (ratio 1.2: 1.0). Relative length of podomeres 2 to 6: 0.85, 0.85, 0.35, 0.35, 1.00. Coxae of 2nd pair of legs broad, medially expanded and rounded, with an almost abortive mediodistal cone; no caudal process. Epigynal plate low triangular, laterally quite weakly emarginate, and without lateral elevation.



FIGS 14-15 *Lissodesmus margaretae* n.sp. 14 - left side of 11th somite of ♂ paratype, dorsal aspect. 15 - right gonopod of ♂ holotype, medial aspect.

Remarks

In the points not mentioned the description of *Lissodesmus modestus* applies.

This is a small species like *L. alisonae* n.sp. from which it is easily distinguished by the quite different structure of the gonopods and the more distinct serrulation of the lateral margin of the paranota.

The species is kindly dedicated to Mrs Margaret A. Williams, entomologist at the Department of Agriculture, Hobart, who made the material available for study.

ACKNOWLEDGEMENTS

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(ms. received 6.IX.1983)

THE OCCURRENCE OF THE SOUTHERN BOTTLE-NOSED WHALE IN TASMANIAN WATERS

by G. Davis and E.R.Guiler
Bellerive, Tasmania and Sandy Bay, Tasmania

(with one table and one text-figure)

ABSTRACT

DAVIS, G. and GUILER, E.R., 1984 (31 viii): The occurrence of the southern bottle-nosed whale in Tasmanian waters. *Pap. Proc. R. Soc. Tasm.*, 118: 103-107. ISSN 0080-4703. 22 Hill Street, Bellerive, Tasmania and 8 Tiersen Place, Sandy Bay, Tasmania.

The first record of this species from Tasmania brings the total number of ziphiids from Tasmanian seas to eight. Details are given of the measurements of the skull.

INTRODUCTION

The Southern Bottle-nosed Whale, *Hyperoodon planifrons* Flower, was described from an imperfect skull from northwestern Australia (Flower 1882). Since that time only 15 further specimens have been reported, three of these being on Australian coasts, but in only five instances was the skull recovered, and only one of these was measured according to the criteria established by Moore (1972).

Moore (1968) considered that the southern representative of this genus differed so greatly from the genotype *H. ampullatus*, from northern waters that he assigned *H. planifrons* to the sub-genus *Frasercetus*.

THE SPECIMEN

The current record is based on an old skull from Ocean Beach, Strahan, which was found in 1981 by Mr M. Schulz, Geography Department, Monash University, who placed it in the dunes. The skull already was dry and weathered. He subsequently relocated the skull and notified Mr H. Wapstra, Tasmanian National Parks and Wildlife Service, who informed one of us (G.D.) who recovered the skull.

It is our opinion that the skull was deposited at least ten years ago as there is no trace of oil and rootlets have penetrated some of the sutures. Moss was found growing on some of the exposed parts of the skull.

Measurements of the skull are given in table 1 which also contains the dimensions that are known for the other *H. planifrons* skulls. The skull is illustrated (fig. 1). The Tasmanian specimen is slightly larger than the South African or South Georgia specimens but smaller than the South Australian material. Fraser (1945) suggested that both sexes were about the same size when adult and that the South American material in the Museo de la Plata described by Moreno (1895) was juvenile. The Tasmanian specimen supports his views as all of Moreno's material as measured by Fraser is much smaller than the present specimen.

Some of the relative dimensions of the Tasmanian specimen are different from those quoted by Moore for the South African material, notably the length from the apex of the rostrum to the most posterior extremity of the maxilla is proportionally greater than might be expected as are also the measurements from the rostrum to the superior nares, the premaxillary crest and the pterygoid sinus. Since the other rostral measurements are not proportionally greater this difference is due to a difference in the relative lengths of the pterygoids of the several specimens.

TABLE 1

THE SKULL OF THE TASMANIAN AND OTHER SPECIMENS OF *HYPEROODON PLANIFRONS*.
Measurements (mm) following the system of Moore (1972). The South African specimen of Tietz (1966) was reported in Moore (1972) and the South Australian specimen is that of Hale (1931).

	1	2	3	4
1 Apex of rostrum to most posterior part of occipital condyles	1300	1210	1193	1391
2 Apex of rostrum to transverse plane at apices of anterior orbital notches	780	715	688	666
3 Apex of rostrum to anterior margin of inferior nares	1020	855		-
4 Apex of rostrum to free apex of pterygoid bone	980	922	948	1150
5 Apex of rostrum to anterior apex of pterygoid	690	596		-
6 Apex of rostrum to apex of maxillae between pterygoids	880	720		-
7 Apex of rostrum to apex of most posterior extremity of either maxilla	1240	1080		-
8 Apex of rostrum to anterior margin of superior nares	1050	890		-
9 Apex of rostrum to anterior part of premaxillary crest	1060	895		-
10 Apex of rostrum to posterior part of temporal fossa	1300	1130		-
12 Apex of rostrum to anterior part of pterygoid sinus	820	595		-
13 Greatest length of temporal fossa	215	210		-
14 Greatest length of orbit	200	156		-
15 Greatest length of right nasal on synvertex of skull	50	85		-
16 Length of nasal suture	105	100		-
17 Greatest breadth of skull across postorbital frontal processes	660	636		-
18 Greatest breadth of skull across zygomatic processes	720	600	601	665
19 Greatest breadth of skull across centre of orbits	590	628		-
20 Least breadth across posterior margin of temporal fossae	500	350		-
21 Greatest lateral spread of occipital condyles	190	204		237
22 Greatest width of wider occipital condyle	100	85		-
23 Greatest length of longer occipital condyle	83	141		174
24 Greatest width of foramen magnum	59	85	60	60
25 Greatest lateral spread of exoccipital bones	520	473		-
26 Greatest lateral spread of nasal bones	56	90		-
27 Greatest distance between maxillary crests	88	88		-
28 Greatest extension of right premaxilla posterior to right nasal	9	30		-
29 Greatest spread of premaxillary crests	330	265		-
30 Narrowest spread of smooth part of premaxillae between nasals	155	181		-
31 Greatest spread of premaxillae anterior to no.30	200	170		295
32 Greatest spread of premaxillae at middle of rostrum	110	103		-
33 Greatest width of rostrum at apices of antorbital notches	450	403	386	500
34 Greatest width of rostrum at apices of prominential notches	198	186		-
35 Greatest width of rostrum at midlength of rostrum	105	140		-
36 Greatest depth of rostrum at midlength of rostrum	106	110		-
37 Greatest transverse width of superior nares	101	100		-
38 Inside width of inferior nares at apices of pterygoid notches	106	144		-
40 Greatest width of temporal fossa perpendicular to long axis	80	120		-
41 Least distance between main (anterior) maxillary foramina	30?	80		-
42 Least distance between premaxillary foramina	73	67		-
43 Posteromesial margin of left maxillary foramen to apex left antorbital tubercle		286		-
44 Greatest length of vomer at surface of palate	440	230		-

Column 1 - Tasmanian specimen
2 - South African specimen
3 - Specimen of Fraser (1945)
4 - South Australian specimen.

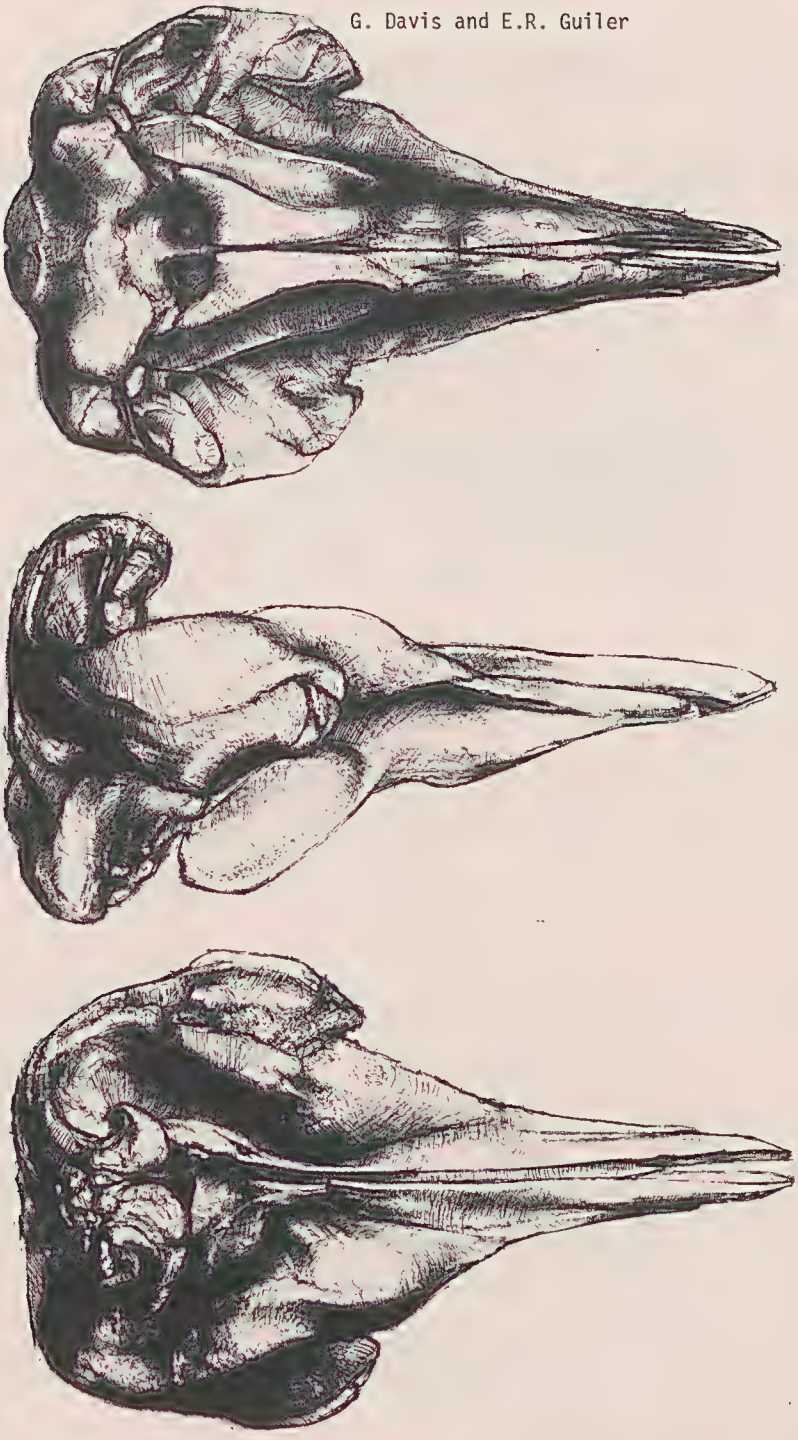

FIG. 1 - Skull of *Hyperoodon planifrons* found on Ocean Beach, Strahan, Tasmania.

The greatest width of the occipital condyle as well as the width of the foramen magnum is greater than in the South African specimen whereas the wider occipital condyle is smaller. The relative width of the nasal bones is also greater in the Tasmanian animal.

The mesorostral canal was not filled by ossified material which the authors believe suggests that the specimen was a female, although Nishiwaki & Kamiya (1958) reported that the type specimen of *Mesoplodon ginkgodens*, another ziphiid, although believed to be a male had a nearly empty mesorostral canal.

DISCUSSION

Very little is known of the biology of this species unlike its boreal counterpart *H. ampullatus*, which is the subject of a fishery (Mitchell 1975). The southern *Hyperoodon* has been seen in a small school of about six individuals by one of the authors (E.R.G.), although Bruyns (1971) saw a group of 40 whales which he believed to be of this species.

The species is reported from Chile (Bruyns 1971, Donoso Barros 1975), Buenos Aires and Patagonia (Moreno 1895), North Island of New Zealand (Waite 1913), Timaru (McCann 1961), Falkland Islands (Hamilton 1952), northwestern Australia (Flower 1882), South Australia (Hale 1931), Victoria (Wakefield 1967), South Africa (Tietz 1966), South Orkney and South Georgia Islands (Fraser 1945). Observations have been made at sea in the Southern Ocean by Tomilin & Latyschev (1967) (quoted in Brownell 1974), and by one of the authors (E.R.G.), who saw a group of between five and seven whales in lat. 65°36'S, long. 75°40'E on 2nd January 1980.

The species clearly is circumpolar in distribution extending from the Southern Ocean as far north as latitude 30°S in all of the oceanic masses. The type locality from the Dampier Archipelago (lat. 21°S) extends the range into the tropics but as this is the only such report it may, in the absence of further records from so far north, be regarded as a vagrant.

The discovery of this skull brings the total number of ziphiid whales positively recorded from Tasmania to eight. The only species which may have a circumpolar distribution but has not been recorded in Tasmania is *Tasmacetus shepherdi* which has been recorded very few times and never yet been recorded alive. The Tasmanian ziphiids represent not only the cosmopolitan and austral circumpolar species but also the tropical *Mesoplodon densirostris* (Guiler 1978).

ACKNOWLEDGEMENTS

We are indebted to Mr M. Schultz of Monash University and to Mr H. Wapstra, National Parks and Wildlife Service for the information leading to the recovery of the skull.

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SEASONAL AND DIEL CHANGES IN SALINITY, TEMPERATURE, DISSOLVED OXYGEN AND SULPHIDE AT A STATION IN THE UPPER DERWENT ESTUARY, SOUTHEASTERN TASMANIA

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(with six text-figures)

ABSTRACT

RITZ, D.A. and BUTTERMORE, R.E., 1984 (31 viii): Seasonal and diel changes in salinity, temperature, dissolved oxygen and sulphide at a station in the upper Derwent estuary, southeastern Tasmania. *Pap. Proc. R. Soc. Tasm.*, 118: 109-115. ISSN 0080-4703. Department of Zoology, University of Tasmania and Tasmanian Department of the Environment, Hobart, Tasmania, Australia.

Temperature, salinity, oxygen saturation and sulphide levels fluctuated widely both seasonally and with depth at a station on the upper Derwent estuary just downstream from a pulp and paper mill. In summer (February) oxygen saturation at the bottom reached a minimum of about 20% and sulphide levels peaked at 11 mg L^{-1}. Conditions at this time would be expected to be lethal to a wide variety of organisms. Some of the possible causes for these changes are discussed.

INTRODUCTION

This study was undertaken as part of a wider programme to investigate the effects of discharging paper mill effluent into the upper Derwent estuary (Matthews 1979). During the study it became evident that, at times, the dissolved oxygen decreased to very low levels while sulphide levels increased considerably. Similar changes in dissolved oxygen and sulphide in estuaries have been reported by other workers (e.g. Bella *et al.* 1972) and levels of the order described are known to be hazardous to resident fauna (e.g. Colby & Smith 1967, Theede 1973, Caldwell 1975).

Since the areas of depleted oxygen and enhanced sulphide coincided with benthic faunal depauperation, it was decided to analyse the extent of the seasonal and diel changes in these factors. Changes in temperature and salinity were monitored simultaneously and pH was recorded. Very few studies of Australian estuaries have included diel and seasonal changes in water properties. An early study (Rochford 1953) recorded without comment oxygen and nutrient levels throughout two 24-hour periods at Old Beach on the Derwent River, and at a station on the Tamar River, northern Tasmania.

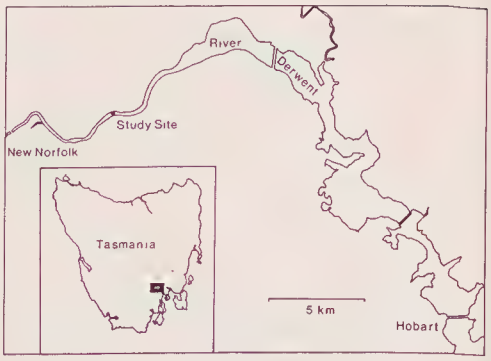
MATERIALS AND METHODS

One sampling station situated about 1 km downstream of the pulp and paper mill at Boyer (fig. 1) was selected for detailed study. This station occurs in the gradient zone of the estuary (Guiler 1955) and is also located near the average position of the toe of the salt wedge (Matthews 1979).

This station was sampled throughout a 24-hour period on four occasions to represent autumn, winter, spring and summer: 24-25th May 1978, 17-18th August 1978, 28-29th November 1978, 27-28th February 1979. Further limited data were obtained on 16th May 1979. Sampling was carried out from an anchored boat and temperature and salinity were measured hourly at surface, 3 m depth and within 0.5 m of the bottom (5-6 m depth depending on state of tide), using an Autolab salinometer (Yeo-Kal, Environmental Electronics). Dissolved oxygen was also measured hourly using a Yellow Springs oxygen meter. Since the cable length was insufficient for the deeper sampling, water samples were obtained with a Van Dorn closing bottle. Every three hours, 1 L samples of water from the three depths were retained and

preserved for later sulphide analysis (A.P.H.A. 1975). At the same time pH was recorded for these samples.

During the first sampling session, it was decided to use a modified Winkler titration (A.P.H.A. 1975) as a check on the performance of the dissolved oxygen meter, and also for measuring dissolved oxygen at 6 m. It was suspected that high concentrations of sulphides and other substances anticipated at this depth might interfere with the probe operation. In practice, the delay between collecting samples and their titration in the laboratory (up to 36 hours) led to results which were obviously inaccurate. High levels of suspended organic matter present in the water at 6 m probably contributed to this error (A.P.H.A. 1975). The Winkler titration was subsequently abandoned and the dissolved oxygen probe was calibrated before use and during operation.



RESULTS

Temperature and Salinity

Temperature and salinity records from the four main sampling dates are given in figures 2 and 3, and figure 4 shows temperature and salinity depth profiles measured in May 1979. The latter sampling occurred at about 2 hours prior to high tide in Hobart. According to Matthews (1979), high tide at Boyer lags behind that at Hobart by about 100 minutes.

In May 1978 when total river discharge was relatively low, i.e. 240×10^6 m^3 (Matthews 1979), salinity fluctuations at 3 m were very marked (fig. 3). The range of salinities experienced at this depth was about 12-24‰ and the cyclical nature of the change was evident to some degree. Surface and bottom salinities remained nearly constant at about 1.5 ‰ and 24.5‰ respectively. Times of high and low tides at Hobart are shown in figure 2 and succeeding figures where appropriate.

The stratification of the river at this time of year is clearly shown in figure 4 where, with a depth change of only 0.5 m, salinity can change by as much as 15‰ and temperature by nearly 7°C.

At times of peak river flow in August 1978, i.e. a total of around 450×10^6 m^3 (Matthews 1979), the water was isothermal and fresh throughout the sampling period (fig. 2). In November when the monthly flow had decreased to less than 200×10^6 m^3 distinct changes in the water characteristics were apparent. The surface water was nearly isohaline and isothermal at around 0.5‰ and 18°C respectively. However, at 3 m there was clear evidence of a tidal current between 1000 and 1600 when the salinity increased from around 2‰ to a maximum of 13‰ at 1400. The deeper water at 6 m remained relatively isohaline and isothermal throughout. It appears from these data as though the tide at Boyer lags behind that at Hobart by rather more than the 100 minutes estimated by Matthews (1979). Because the station was situated in a small bay out of the main river channel the tidal effect could have been further delayed by local eddy circulation.

In February when river flow was at a minimum, 145×10^6 m^3 (Matthews 1979), salinity fluctuations at both 3 m and 6 m were particularly intense (fig. 3). Surface salinity remained uniform at about 1‰ , but that at 3 m showed a cyclic fluctuation between about 2‰ and 14‰. Bottom salinity varied between 18‰ and 24‰ with a less obvious cycle. Temperature varied only between about 16° and 20°C from surface to bottom. Apparently there is little difference in temperature between fresh and salt water at this time of year.

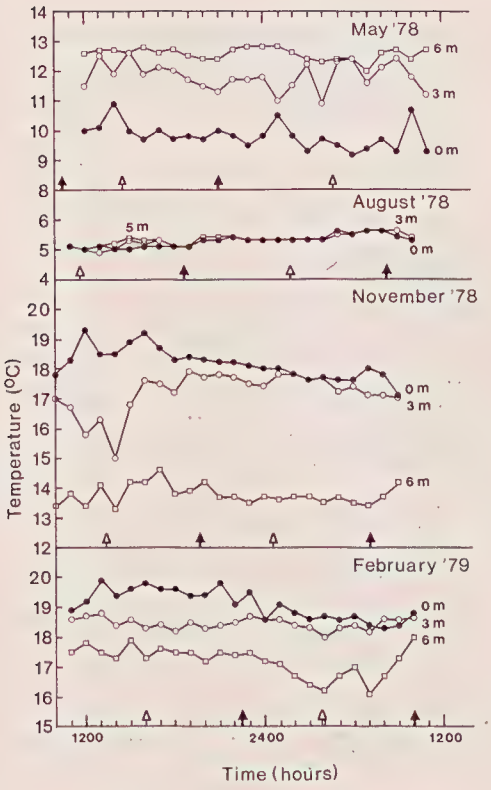


FIG. 2 - Temperatures at study site during four sampling periods and at three depths. ↑ - time of high tide; ↓ - time of low tide.

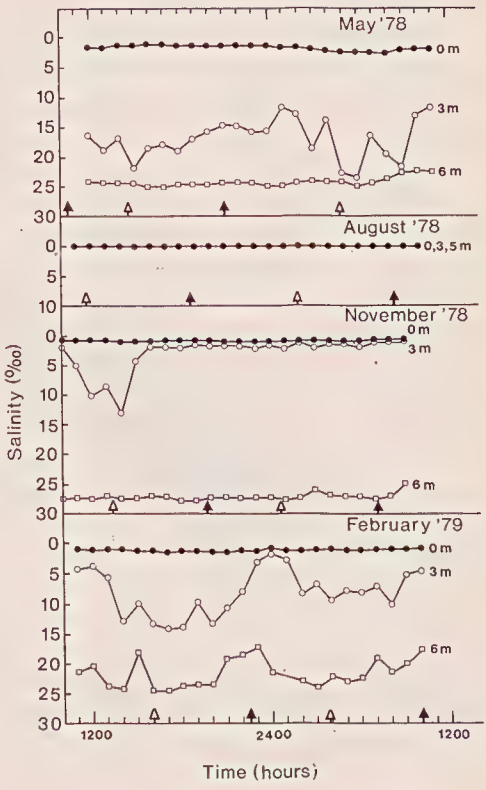


FIG. 3 - Salinity at study site during four sampling periods and at three depths. ↑ - time of high tide; ↓ - time of low tide.

Dissolved Oxygen

As might be expected the surface oxygen levels remained high, i.e. between 80 and 100% saturation or slightly above throughout the study. However, subsurface oxygen levels were subject to considerable fluctuation. In August when the water column was entirely fresh and about 5°C, oxygen saturation at all depths remained close to 100% (fig. 5). At other times oxygen saturation was usually somewhat lower and values at the surface and at 3 m coincided fairly closely. Occasionally there were departures from this pattern, e.g. at 1400 to 1600 in February and at 0600 to 0900 in May where the values at the surface and at 3 m differed by up to 20%. The reasons for this may have been the sharp discontinuity just below 3 m (fig. 4). Slight displacement of the water sampling bottle either up or down could have resulted in large differences in the measured oxygen. The divergence in oxygen values at 0 m and 3 m could have been the result of tidal influence although they do not coincide with the obviously tidally related salinity cycles (fig. 3). In fact, in February, rising salinities at 3 m and below between 1300 and 2000 suggesting the input of high salinity water on the rising tide, coincided with a drop in oxygen saturation at 3 m.

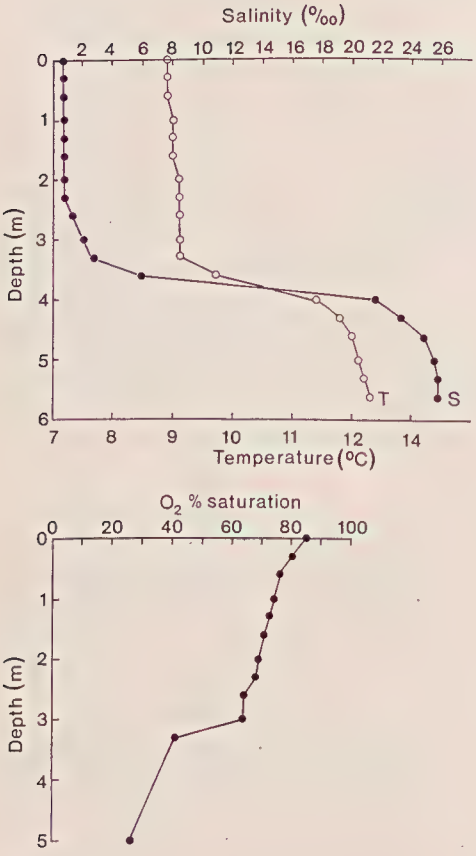


FIG. 4 - A: Temperature and salinity/depth profiles. B: Oxygen saturation/depth profile. All measurements on 16.5.79.

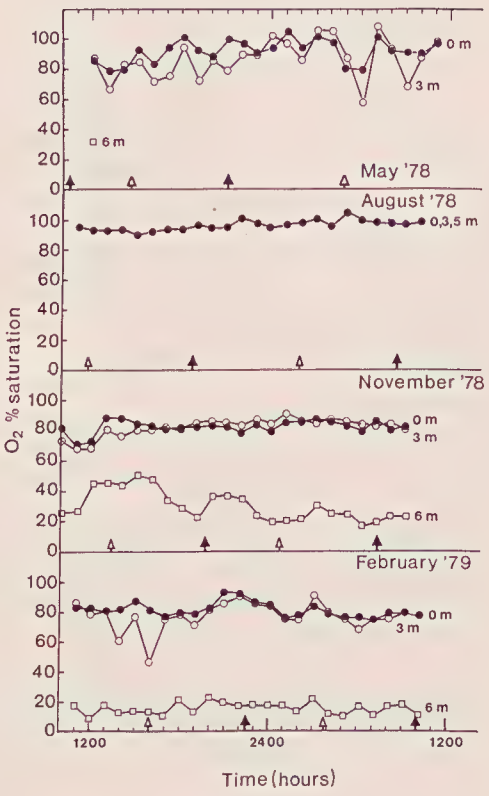


FIG. 5 - Oxygen saturation at study site during four sampling periods and at three depths. ↑ - time of high tide; ↓ - time of low tide.

Apart from the August samples, oxygen saturation values at 6 m were, with only one exception, less than 50%. The single reading of 32% saturation in May 1978 was supplemented by very similar values recorded in May 1979 (fig. 4).

Oxygen saturation values at 6 m in November showed considerable fluctuation between about 50% and 20%. The period of highest oxygen levels at 6 m, i.e. between 1200 and 1600 coincided with the period of highest salinities at 3 m (fig. 3). Thus oxygen may have been replenished by the rising tide. The oxygen levels at 3 m did not show the same cyclical change but this may have resulted from the inherent instability of the mid-depth (fig. 4) as explained above.

Oxygen saturation values showed no clear diel cycles.

Sulphide Levels

In May the surface and 3 m sulphide levels remained uniformly low whilst those at 6 m reached a maximum of 2.8 mg L^{-1} at 0600 (fig. 6). The slight fluctuations recorded at 6 m could have been tidally related since the sampling routine (3-hourly) may have masked the variation. However, they are not mirrored at 3 m where the greatest salinity fluctuations were experienced (fig. 3).

The August and November sulphide levels were uniformly low at all depths (fig. 6). However, in February, the highest levels and the greatest fluctuations were recorded. Highest concentrations reached were 10 to 11 mg L^{-1} at 6 m at 2100 and 0300 respectively. The period between these two times corresponds roughly to the period of lowest salinity and hence ebbing tide. Conversely the period of lowest sulphide levels corresponds roughly to the period of highest salinities, i.e. 1400 to 2000 and 0400 to 0800. However the inverse correlation between salinity and sulphide concentration at both 3 m and 6 m proved not to be significant ($P > 0.05$).

The fluctuations in sulphide levels do not obviously coincide with similar fluctuations in oxygen saturation although any possible correspondence between the two may have been masked to some extent by the different sampling regimes.

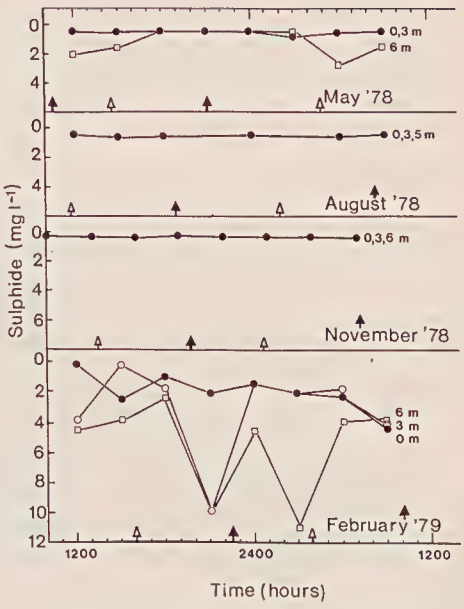


FIG. 6 - Sulphide concentration at study site during four sampling periods and at three depths. ↑ - time of high tide; ↓ - time of low tide.

pH

pH was lowest in August, i.e. 6.5 to 6.8, when the site was dominated by fresh water at all depths. At other times the pH varied little with a range from 6.8 to 7.2 with no seasonal trend.

DISCUSSION

Matthews (1979) collated physico-chemical data on the upper Derwent estuary and presented an interpretation of the hydrodynamic regime though his report contains serious errors. His conclusions about tidal exchange and particle transport rates are based on incorrect calculations of volume entering the estuary on a flood tide. The volume of freshwater entering the upper estuary closely matches the tidal prism in winter and the ratio is about 1:3 in summer. Thus the stratification and circulation pattern approach the classical salt-wedge estuary condition in winter but represent a partially mixed condition in summer (Perkins 1974).

One of Matthews' conclusions was that suspended wood fibre in the paper mill effluent entering the river at Boyer could accumulate and be deposited in the region with which the present study is concerned. He proposed a two-layer flow regime though due to the miscalculation assumed that the subsurface landward flow was much weaker than is probably the case. Without knowledge of such processes as waterlogging, flocculation and localized circulation patterns it is not possible to predict where particulate matter from the effluent would be deposited. However, the data on N.F.R. (non-filterable residue) and

sediment organic content support the suggestion that the particulate matter is deposited over a region extending at least 10 km downstream from the paper mill (Matthews 1979). Concentration of particulate matter seems to occur particularly over a stretch extending 5 km downstream from the mill except during periods of maximum river discharge when there is effective flushing. Slow decomposition of fibre mats would exert an oxygen demand on the overlying bottom water. Matthews speculated that photosynthetic activity is inhibited by the discolouration of the surface waters. Lack of a diel cycle in dissolved oxygen reported in the present study supports the argument that photosynthetic activity is insignificant in this part of the river. Interestingly the data of Rochford (1953) for dissolved oxygen in Tasmanian rivers shows no clear diel cycle.

According to Bella *et al.* (1972), hydrogen sulphide levels of 1 mg L^{-1} are not uncommon in water overlying sediments in Oregon estuaries. Where poor flushing characteristics are combined with such factors as high organic content, for example wood chips, shallow water depths and low dissolved oxygen, sulphide concentrations in the water were found to be as high as 12-16 mg L^{-1}. Such a description is apt for the station worked in the present paper especially in February when temperatures were highest, dissolved oxygen was lowest, and river flow reduced to a minimum. At this time of year levels of sulphide at the Derwent station were comparable to those reported by Bella *et al.* In fact the odour of hydrogen sulphide was conspicuously strong in February particularly at night.

The fluctuations in sulphide levels at the Derwent sampling station in February appear to be independent of dissolved oxygen. Bella *et al.* (1972) noted an inverse relationship between the two and Wheatland (1954) described how they might interact in a polluted estuary. The latter author described a lag phase in build-up of sulphide following a gradual decline in dissolved oxygen as the water warms up. This is apparently the case at the Derwent sampling station in November where dissolved oxygen levels at the bottom were nearly always less than 50% saturated while sulphide levels were still negligible.

Hydrogen sulphide occurs in solution as part of a pH-dependent system, i.e. $H_2S \rightleftarrows HS^- \rightleftarrows S^{2-}$. At pH levels recorded during the present study, i.e. between 6.5 and 7.2, free sulphides are divided between the forms H_2S and HS^- (Bella *et al.* 1972). Increase of the pH towards 8 would increase the toxicity of H_2S because it would shift the equilibrium towards the dissociated species (Theede 1973). Sulphide levels reported for the sampling station examined in this study would almost certainly be lethal to a wide range of organisms. Benthic diatoms succumbed within 48 hours to levels of 0.9-6.8 mM (31-231 mg L^{-1}), showing a high degree of tolerance (Admiraal 1979). On the other hand, the 96 hour LC50 for an amphipod was 0.2 mg L^{-1} and early embryos of *Crassostrea gigas* were drastically affected within 2 hours of exposure to only 0.32 mg L^{-1} (Caldwell 1975). Concentrations of less than 0.075 mg L^{-1} at pH 7.6-8 were reported by Colby & Smith (1967) to be harmful to several fish and particularly so to their eggs and fry.

During spring and summer months, the region of the Derwent estuary described here is almost devoid of macrobenthic organisms exceeding 500 µm (Matthews 1979). With increasing river flow in autumn (May), oxygen levels recover somewhat and sulphide levels are considerably reduced. Recolonization of the site, at least by polychaetes, is apparent at about this time. With maximum river flow in winter the site is flushed completely with fresh water, dissolved oxygen is restored to full saturation and sulphide levels are reduced still further. The steady-state location of the toe of the salt wedge lies in the region of the river investigated in this paper. The variable environmental conditions implicit in such a situation might be expected to suppress the faunal diversity even without the intervention of man-made effluent discharges. Matthews (1979) described a marked decrease in macrobenthic faunal diversity in this region of the river which he acknowledged could be partly attributable to its ecotonal (transitional) nature. Discharge of effluent with high oxygen demand could only exacerbate such a situation. The main source of concern is likely to arise from the aggregation and deposition of wood fibre the subsequent breakdown of which exerts a heavy B.O.D. and C.O.D. on the overlying water. Most severe effects are experienced in summer when dissolved oxygen levels reach a minimum, sulphide production is greatest and hydrogen sulphide gas is released at the surface.

ACKNOWLEDGEMENTS

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CETACEAN STRANDINGS IN TASMANIA FROM FEBRUARY 1978 TO MAY 1983

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(with one table, one text-figure and five plates)

ABSTRACT

McMANUS, T.J., WAPSTRA, J.E., GUILER, E.R., MUNDAY, B.L. and OBENDORF, D.L., 1984 (31 viii): Cetacean strandings in Tasmania from February 1978 to May 1983. *Pap. Proc. R. Soc. Tasm.*, 118: 117-135, pls 1-5. ISSN 0080-4703. Department of Agriculture, Falmouth and Mt Pleasant, Tasmania, National Parks and Wildlife Service, Hobart and University of Tasmania, Hobart, Tasmania.

This paper presents a summary of 46 recent whale strandings involving 13 species and 497 animals, as well as six strandings not included in the previous summary by Guiler (1978). Two new species are added to the 22 previously recorded for Tasmania. Details of rescue operations, including an evaluation of current procedures, are given. Causes of the stranding phenomenon are discussed with particular reference to events in Tasmania. Results of pathological examinations are given, together with analyses of heavy metal and pesticide residue in tissues.

INTRODUCTION

Records of strandings of cetaceans around Tasmania's coastline date from the mid-1800s (Scott 1942, Davies 1963, Guiler 1978). In recent years the frequency of stranding reports has increased, possibly as a consequence of easier access to remote stretches of coastline, and an enhanced public and government awareness of cetaceans. This paper presents an update on Tasmanian strandings from 1945-78 reported by Guiler (1978). Twenty-two cetacean species are listed as having stranded in Tasmanian waters since records began (Guiler 1978), although the evidence for some of these is scanty. This paper adds two species, Sei Whale *Balaenoptera borealis* and Southern Bottlenosed Whale *Hyperoodon planifrons*, to the previous record.

As elsewhere, cetacean strandings on Tasmanian shores are either single, multiple or mass, the latter involving up to 300 individuals. Several possible explanatory theories have been proposed for these events (Bergin 1978, Geraci & St Aubin 1979, Cordes 1982). Single animals were generally assumed to have beached themselves because they were sick or injured. However, recent studies in Tasmania indicate that this is not always so (Munday *et al.* 1982). Occasionally topographical factors or turbulent weather conditions are involved whereby individuals or even groups become "lost" particularly during spring-tides, leaving themselves hopelessly stranded. Other factors such as severe ear parasitism may also sometimes contribute to strandings (Geraci & St Aubin 1979). In some single strandings the whale had died at sea and was washed ashore.

From 1978 to 31 May 1983, 46 cetacean strandings involving 13 species and 497 animals were recorded in Tasmania. These are summarised in table 1. Because the occurrence of "spring" tides associated with the new and full moon is frequently cited as a factor in strandings, where applicable the nearest dates of these two lunar phases are included. The relationship between phases of the moon and "spring" and "neap" tides, is an extremely complex one. "Spring" tides do not occur simultaneously with their respective lunar phase, but approximately one to five days later depending on the locality and time of year. The actual number of "spring" tides month by month also varies, as does their height. In table 1, where a particular stranding might conceivably relate to a lunar-induced "spring" tide, the date of the relevant moon phase is underlined.

Cetacean Strandings in Tasmania from February 1978 to May 1983

TABLE 1

CHRONOLOGICAL SUMMARY OF STRANDINGS, FEBRUARY 1978-MAY 1983

	Date	Number and Species	Location	Nearest Full Moon	Nearest New Moon
(1)	26-2-1978	79 Pilot Whales	Sellars Point Flinders Island	23-2-78	9-3-78
(2)	1-3-1978	21 Pilot Whales	Stephens Beach, Port Davey	23-2-78	9-3-78
(3)	27-4-1978	1 Bottlenosed Dolphin	Adventure Bay Bruny Island	23-4-78	7-5-78
(4)	?-6-1978	1 Common Dolphin	Adventure Bay Bruny Island	N/A	N/A
(5)	29-8-1978	1 Sperm Whale	Settlement Beach Flinders Island	16-9-78	2-9-78
(6)	1-11-1978	2 Bottlenosed Dolphins	Pittwater, near Midway Point	14-11-78	31-10-78
(7)	22-2-1979	1 Cuvier's Beaked Whale	Bridport	12-2-79	27-2-79
(8)	4-3-1979	34 Pilot Whales	Newmans Beach, Koonya	14-3-79	27-2-79
(9)	2-2-1980	1 Killer Whale	Sisters Beach	1-2-80	16-2-80
(10)	?-3-1980	3 Sperm Whales	South of Trial Harbour	N/A	N/A
(11)	?-4-1980	1 Southern Right Whale	Henty River, south of Trial Harbour	N/A	N/A
(12)	30-9-1980	2 Bottlenosed Dolphins	Ralphs Bay, South Arm	24-9-80	9-10-80
(13)	31-10-1980	117 Pilot Whales	Patriarchs Inlet, Flinders Island	24-10-80	8-11-80
(14)	?-11-1980	1 Sei Whale	Cloudy Bay Bruny Island	N/A	N/A
(15)	?-12-1980	1 Southern Right Whale	Actaeon Island, Nr. Recherche Bay	N/A	N/A
(16)	?-1-1981	3 Bottlenosed Dolphins	Riedle Bay Maria Island	N/A	N/A
(17)	15-1-1981	26 Sperm Whales	Macquarie Harbour, Nr. Strahan	20-1-81	6-1-81
(18)	?-2-1981	1 Bottlenosed Dolphin	Eaglehawk Neck	N/A	N/A
(19)	?-2-1981	1 Humpback Whale	Lagoon River, south of Sandy Cape	N/A	N/A
(20)	27-5-1981	1 Cuvier's Beaked Whale	Lewisham	19-5-81	2-6-81
(21)	17-6-1981	1 Minke Whale	Cremorne	17-6-81	2-6-81
(22)	8-9-1981	183 Pilot Whales	McIntyres Beach Falmouth	14-9-81	29-8-81

(23)	10-9-1981	1 Pygmy Right Whale	West Beach, Stanley	14-9-81	29-8-81
(24)	25-9-1981	2 Sperm Whales	Fotheringate Bay, Flinders Island	14-9-81	28-9-81
(25)	27-12-1981	1 Gray's Beaked Whale	Nine Mile Beach, Swansea	11-12-81	26-12-81
(26)	3-1-1981	3 Strap-toothed Whales	Cloudy Bay, Bruny Island	10-1-82	26-12-81
(27)	7-1-1982	51 Pilot Whales	Macquarie Harbour	10-1-82	26-12-81
(28)	8-1-1982	1 Bottlenosed Dolphin	Ocean Beach, Strahan	10-1-82	26-12-81
(29)	23-1-1982	1 Sperm Whale	Perkins Bay, Stanley	10-1-82	25-1-82
(30)	26-1-1982	14 Sperm Whales	Ocean Beach, Strahan	8-2-82	25-1-82
(31)	9-2-1982	9 Sperm Whales	Perkins Bay, Stanley	8-2-82	25-1-82
(32)	9-3-1982	2 Common Dolphins	Little Taylors Bay, Bruny Island	10-3-82	24-2-82
(33)	1-4-1982	1 Bottlenosed Dolphin	Gorringes Beach South Arm	9-4-82	25-3-82
(34)	14-6-1982	1 Pygmy Right Whale	West Inlet Stanley	7-6-82	21-6-82
(35)	13-9-1982	1 Pygmy Right Whale	Darlington, Maria Island	3-9-82	17-9-82
(36)	1-10-1982	2 Bottlenosed Dolphins	Pittwater, near Midway Point	3-10-82	17-9-82
(37)	?-10-1982	1 Sperm Whale	Ringarooma Bay	N/A	N/A
(38)	5-1-1983	1 Pygmy Right Whale	Trumpeter Bay, Bruny Island	30-12-82	14-1-83
(39)	14-1-1983	1 Sperm Whale	Temma, west coast	29-1-83	14-1-83
(40)	14-1-1983	1 Pilot Whale	Howells Point, Maria Island	29-1-83	14-1-83
(41)	14-1-1983	2 Strap-toothed Whales	Cape Portland, north-east coast	29-1-83	14-1-83
(42)	24-1-1983	1 Bottlenosed Dolphin	Seven Mile Beach, southern Tasmania	29-1-83	14-1-83
(43)	26-1-1983	1 Pygmy Right Whale	West Beach, Stanley	29-1-83	14-1-83
(44)	?-1-1983	1 Strap-toothed Whale	Plain Place Beach, Triabunna	N/A	N/A
(45)	4-2-1983	15 Common Dolphins	Ralphs Bay South Arm	29-1-83	13-2-83
(46)	19-4-1983	1 Sperm Whale	Prion Beach, south coast	13-4-83	27-4-83

TOTAL = 497 CETACEANS

Of the 46 strandings, 16 were discovered and reported in time for rescue operations to be mounted. Since 1981, rescues in Tasmania have become increasingly efficient and successful as a result of improved planning and co-operation between the National Parks and Wildlife Service and other government authorities and volunteer organisations. The paper describes individual rescues in some detail and discusses aspects which are of importance to the development and refinement of contingency plans for whale rescues, locally and elsewhere.

DETAILS OF INDIVIDUAL STRANDINGS

The following is a summary of cetacean strandings to 31 May 1983 and follows on from Guiler (1978). Descriptions of events are arranged in taxonomic order according to Watson (1981) and sequentially within each species. For each event, the stranding number used in the chronological summary of table 1, is given except for strandings additional to the previous summary for 1945-78 in Guiler (1978). These numbers are also used in figure 1 which plots the locations of strandings. Certain additional information, including standard measurements (if available), site topography, sea conditions and tides, unless essential for an understanding of the events described, are given in an Appendix which may be obtained from the editor.

In the few instances which have not been investigated on site by one or more of the authors, descriptions are based on detailed reports submitted and identifications confirmed from photographs or clear descriptions of distinctive features of the whales involved.

Baleen Whales (Mysticeti)

Southern Right Whale *Balaena glacialis*

Henty River, south of Trial Harbour, April 1980 (No.11)
The carcass was badly decomposed when discovered.

Actaeon Island, Recherche Bay, November/December 1980 (No.15)
This animal was discovered long after any useful examination was possible. Its length - 7 m, indicates it was a juvenile, but no cause of the stranding could be elicited. The two Southern Right Whale strandings cited in this paper are the first reported in Tasmania for more than a century.

Pygmy Right Whale *Caperea marginata*

Fotheringate Bay, Flinders Island, May 1975
A mother and calf, no other details available.

West Beach, Stanley, 10 September 1981 (No.23)
Details of this animal are given in a recent paper in these proceedings (Munday *et al.* 1982), and in the Appendices herewith. It was a pregnant female in apparent good health 6.45 m long, containing a 380 mm female foetus. There was no significant pathology.

West Inlet, Stanley, 14 June 1982 (No.34)
This was also a pregnant female which stranded 4 km south of stranding number 23. The most notable feature was that despite being only 6 m long itself, this whale contained a full-term foetus measuring 2 m, i.e. one third of its mother's length. It too was female. Rescue attempts failed and the animal died 16 hours after stranding. No pathological lesions were detected on post mortem examination.

Darlington, Maria Island, 13 September 1982 (No.35)
The only male among the four whose sex was determined. It was quite large for the species being 6.09 m long, and its skin surface bore numerous circular scars, some recent, some old, on the lower sides and ventral abdomen. These scars were 40-50 mm in diameter on average, and occurred either singly or in multiples of two or three. They are regular lesions on adult Pygmy Right Whales stranded in Tasmania, and are consistent with the predatory effects of "cookie-cutter" sharks, e.g. *Isistius brasiliensis*, as described by Watson (1981).

FIG. 1 - Locations of cetacean strandings in Tasmania 1978-1983. Numbers as in table 1.

This whale came ashore adjacent to the base of the jetty in Darlington Bay at 7.30 p.m. It appeared weak and died at noon the next day whilst rescue efforts were in progress. Due to its proximity to a popular tourist venue, only limited post mortem sampling was possible.

Trumpeter Bay, North Bruny Island, 5 January 1983 (No.38)
A rare instance of a baleen whale being returned successfully to the sea. This was achieved by a local resident who used the sand-filled scoop of a front-end loader to push the animal off the beach. After initial disorientation, during which the equipment was used to prevent re-beaching, the whale headed slowly out to sea. It was last observed swimming strongly beyond the confines of the bay. The animal was estimated to measure 5 m, but its sex was not determined.

West Beach, Stanley, 26 January 1983 (No.43)
A female, approximately 5 m in length, with no obvious abnormalities. Unfortunately the head had been removed by a member of the public before postmortem examination began, but inspection of internal organs revealed no significant pathology. She was not pregnant. Samples were collected for heavy metal and insecticide residue tests.

The Pygmy Right Whale is by far the most common baleen whale stranded in Tasmanian waters. The five new records in this paper continue the sequence of regular reports extending back over 50 years (Scott 1942, Davies & Guiler 1957, Guiler 1978).

Minke Whale *Balaenoptera acutorostrata*

Cremorne, 17 June 1981 (No.21)
This animal was a newly born female calf, 2.24 m long, still bleeding from its umbilicus. As it appeared to be in good condition, it was released in Frederick Henry Bay about 1.5 km offshore from the point of stranding, in the hope that it would rejoin its mother. However, early next day the whale was found restranded in virtually the same place and died shortly after. Two of the four previous strandings of the species also involved recently born calves and occurred during early winter, indicating that calving may take place in or close to Tasmanian waters (Guiler 1978).

Sei Whale *Balaenoptera borealis*
Cloudy Bay, South Bruny Island, October/November 1980 (No.14)
The first report of a Sei Whale stranding in Tasmania. It occurred at the southern end of the beach. The skull and baleen were collected from the decomposed carcass. The whale was a juvenile, approximately 7 m long.

Humpback Whale *Megaptera novaeangliae*
Lagoon River, 8 km south of Sandy Cape, February 1981 (No.19)
The carcass was decomposed and no other information is available.

Toothed Whales (*Odontoceti*)

Cuvier's Beaked Whale *Ziphius cavirostris*
Bridport, 22 February 1979 (No.7)
The animal was dead when discovered but apart from identification, was not examined closely.

Lewisham, 27 May 1981 (No.20; plate 1)
This whale had been reported in the vicinity for two days prior to stranding. Eventually it came alongside a rocky platform projecting into shallow water, belly down and facing landwards. Rescue efforts failed as boats or vehicles could not reach the site and the animal was too heavy to be moved manually. As the tide rose the whale attempted to free itself by violent thrashing but unfortunately drowned.

The whale was a male, 5.78 m long. It had many characteristic double-track scars criss-crossing its back and sides. These parallel scars result from fighting with other males, the distance between the lines being equivalent to the gap between the two conical teeth at the end of the lower jaw of males of this species (Watson 1981). It also had

PLATE 1 - *Isistius* scars and characteristic double-track scars from fighting, Cuvier's Beaked Whale (No.20). Photo: A. Wapstra.

numerous round and oval scars similar to those caused by "cookie-cutter" sharks, as described by Watson (1981).

Both records conform with earlier ones (Guiler 1978) in that they are of single animals.

Southern Bottlenosed Whale *Hyperoodon planifrons*

Ocean Beach, Strahan, date unknown

This record is based on a large dried skull found by M. Schulz of Monash University on 25 February 1981 on Ocean Beach, near the entrance to Macquarie Harbour (Strahan). It was half covered by sand, perfectly clean and apparently older than the records presented in this paper. It was reported and collected in 1983 by which time some moss growth had occurred. Although the mandible was missing, the upper jaw and cranium were almost entirely intact, permitting positive identification. This is the first record of Southern Bottlenosed Whale in Tasmanian waters. The skull is described by Davis & Guiler (1984).

Gray's Beaked Whale *Mesoplodon grayi*

Apple Orchard Point, Cape Barren Island, June/July 1972

Identified from skull. Carcass decomposing when found, no other information available.

Nine Mile Beach, Swansea, 27 December 1981 (No.25)

The animal was reported belatedly, precluding close examination except for identification from the skull. Although commonly stranded on New Zealand shores, this record is only the fourth for Tasmania.

Strap-Toothed Whale *Mesoplodon layardi*

Cloudy Bay, South Bruny Island, 3 January 1982 (No.26)

Three freshly dead females of similar length (4.53, 4.59 and 4.86 m). They were first observed swimming close inshore in very rough conditions the previous evening.

Cape Portland, approximately 14 January 1983 (No.41)

One large female whale was found dead on Little Musselroe Beach on 14 January and a small juvenile male was found washed up a few days later on the rocks of Lanoma Point, some 6 km to the west. A mother-calf relationship can only be speculative due to the differences in the dates and locations of the whales being discovered. Details of the stranding and skull description are given in Guiler (1984).

Plain Place Beach, Triabunna, January 1983 (No.44)
The specimen was reported in May by a local resident who had first seen the carcass in March. At that time it was relatively intact and measured approximately 5.5 m. Further local enquiries revealed that the animal had stranded in January. Examination of the remains showed that a section of the rostrum had been removed with a saw, presumably for its impressive teeth, but other skull features allowed positive identification of the species as well as its sex (male).

Sperm Whale *Physeter macrocephalus*

Patriarchs Inlet, Flinders Island, 1975
Remains of three animals, no other information available.

Settlement Beach, Flinders Island, 29 August 1978 (No.5)
This stranding of a large animal was reported by Rounsevell *et al.* (1981).

South of Trial Harbour, March 1980 (No.10)
Decomposing corpses of three animals.

Macquarie Harbour, Strahan, 15 January 1981 (No.17)
A mass stranding of 26 animals. The most interesting aspect of this event was that nine whales returned to deep water, five voluntarily and four with some assistance. Rounsevell *et al.* (1981) stated this to be the first Australian record of Sperm Whales leaving a mass stranding while others remained alive. Although one of them is known to have restranded and died, the fate of the other eight is unknown.

Fotheringate Bay, Flinders Island, about 25 September 1981 (No.24)
Two mature males, 16.0 and 16.2 m respectively, which had been dead for about two weeks. Advanced decomposition precluded detailed examination.

Perkins Bay, Stanley, 23 January 1982 (No.29)
An adult female 10.6 m long. Next day it evulsed a 4.1 m male calf. Difficult access to the site precluded pathological examination.

Ocean Beach, Strahan, about 26 January 1982 (No.30; plate 2)
A mass stranding of 14 animals. When discovered the carcasses had commenced to decompose and one female had either aborted or evulsed a 3.96 m male foetus. Abdominal cavities were ruptured and skin had blistered and extruded fat. Numerous whales had evidence of squid sucker marks on their bodies especially around their heads, a common phenomenon also mentioned by Rounsevell *et al.* (1981), in reference to stranding number 17.

The sex ratio was three males to 11 females, the longest male being 14.30 m and the longest female 11.65 m. Several jaws were collected for age determination but no further examination was possible.

Perkins Bay, Stanley, 9 February 1982 (No.31)
Nine animals were first observed swimming offshore in the shallows at about 6 p.m. approximately one hour prior to the second lowest spring ebb-tide for the month of February. They became stranded later that same evening but four of them were refloated by the high spring tide just after midnight and next morning only five whales remained - all adult females. Whether the escapees survived is not known; those remaining were all dead by the following evening.

Lengths ranged from 10.40 m to 11.25 m. They rapidly decomposed in the summer sun and by the time a pathologist could reach the site, little could be deduced. A single post mortem was conducted and death was found to be due to drowning. Sections of skulls were collected for anatomical information and these are at Mt Pleasant Laboratories, Department of Agriculture, Launceston.

Ringarooma Bay, October 1982 (No.37)
Putrid carcass found some weeks after stranding.

PLATE 2 - Sperm Whales beached at Strahan (No.30). Photo: A. Wapstra.

Temma, about 14 January 1983 (No.39)
Washed up dead according to local residents. It was an adult female, approximately 11.10 m long, and putrid when examined on 28 January.

Prion Beach, 19 April 1983 (No.46)
A single animal found freshly dead, rolling in the surf. Length estimated "25 feet", sex unknown. A feature was its unusual colour, said to be "nearly white".

Pilot Whale *Globicephala melaena*
Sellars Point, Flinders Island, about 26 February 1978 (No.1)
Mass stranding of 79 animals, which could not be examined until several days after the actual stranding by which time all the whales were dead and some partially buried. The majority were females two of which evulsed a foetus after stranding. They beached themselves on a sand spit extending off-shore from the Point, and when discovered were all facing in a northerly direction indicating an approach from the south between Babel Island - towards which the sand spit extends - and Flinders Island. The "spring" tide may well have had a bearing on this stranding.

Stephens Beach, Port Davey, about 1 March 1978 (No.2)
Mass stranding of 21 animals. All the whales were reported to be melanic.

Newmans Beach, Koonya, 4 March 1979 (No.8)
Mass stranding of 34 animals. A wide very shallow beach where the tide recedes about 400 m at full ebb, leaving numerous shallow pools capable of causing confused echolocation to whales passing over the area at high water. The sea beyond the ebb tide-line is also shallow. All the whales were stranded well up the beach just below the *Zostera* beds, by a receding "spring" tide. Despite rescue attempts all the whales eventually died.

Patriarchs Inlet, Flinders Island, 31 October 1980 (No.13; plate 3)
A mass stranding of 117 animals, unusual in that it involved only eight adult males, the remainder being 103 females and six calves. It appeared that the biggest bull came ashore first, to be followed by the herd, 70 of which were clustered around this animal. Two trail-bike riders, who found the whales while many were still alive, attempted to coax some of the smaller ones back into deep water but they swam back to the beach immediately on release. All the whales eventually died.

PLATE 3 - Aerial view of stranded Pilot Whales at Patriarchs Inlet (No.13). Photo by courtesy of Mercury, Hobart.

Falmouth, 8 September 1981 (No.22; plates 4 and 5)

A mass stranding of 183 animals. They came ashore at McIntyres Beach, 8 km south of Falmouth on Tasmania's east coast. One whale was observed to swim away immediately. The rest remained and were accurately counted, the total being 182. A strong off-shore westerly wind was blowing against an easterly swell; the wind continued to strengthen and by midday had reached gale force.

During the afternoon attempts to save some of the whales failed and were eventually abandoned due to the dangerous conditions. By mid-afternoon more than half the whales were dead, including a group of eight mature males at the northern end of the beach thought to have been the first to strand.

Next morning the weather was much calmer. By then, there were carcasses along the length of the beach and floating in the sea nearby. Only 11 whales remained alive. About a third of the bodies were half or three-quarters buried in sand at the water's edge. Carcasses floating in the sea were also inaccessible. As many as possible were sexed (78) and measured (98). The length of the longest measured male was 5.77 m and the longest female 4.79 m. The sex ratio was 37 males:41 females. (In a mass stranding of 200 individuals near Dunalley in 1975, recorded by Guiler (1978), the longest male was 6.2 m, the longest female 5.55 m, and the sex ratio 39 males:54 females.)

PLATE 4 - Mass stranding of Pilot Whales at Falmouth (No.22) showing rough weather. Photo: A Wapstra.

The 11 live whales were manhandled back into the sea by members of the public under the direction of "Project Jonah" and Government officers. They joined two whales similarly released during the previous night. It is doubtful whether these animals survived. Subsequent to the stranding, three freshly dead whales were washed onto rocks beyond the northern end of McIntyres Beach on 11 September. Two days later a carcass appeared on Red Bill Beach at Bicheno about 32 km south. One animal was seen swimming sluggishly off Falmouth on 15 September. Later a 5.1 m male carcass was discovered on Steels Beach, Falmouth, 2 km north of the township on 24 October. It had been dead approximately three weeks. Three more freshly dead carcasses were washed ashore at the southern end of McIntyres Beach on 27 September. Finally a decomposed carcass was found on Beaumaris Beach, North Scamander on 4 October. It is believed that at least some of these later strandings involved animals rescued earlier, although there is no proof as they had not been tagged.

The topography of the bay at McIntyres Beach is typical of what has frequently been described as a "whale trap". It is a 1 km curved stretch of sand flanked by two rocky headlands, Burying Point to the north and Ironhouse Point to the south. About 300 m due east of Ironhouse Point is a large rocky outcrop above sea level. It is the highest part of a submerged reef which curves inshore and rises to connect with a rocky outcrop extending from the beach. A further submerged reef covered with kelp runs parallel to the beach about 300 m offshore. An additional hazard in the form of a parallel sandbar is located 100 m offshore. No cetacean strandings either single or multiple had been recorded there before. However, a year previously, part of a school of dolphins had become temporarily "lost" inside the reef.

Four bulls (from the northern end), plus a cow and calf were autopsied before being buried with the others. The main post mortem findings are tabulated in Appendix 1. An outstanding feature was the presence of large numbers (average 2300 , range 1140-4200, number of ears examined 6) of nematode worms *Stenurus globicephalae* in the ear canals, guttural pouches and auditory sinuses of the four mature males (plate 5). The infestation was accompanied by varying quantities of greyish-white frothy exudate. Very few parasites (142 in left side) were found in the ear passages of the single, mature female which was examined. The presence of water in collapsed lungs of three whales suggested that the final cause of death was drowning.

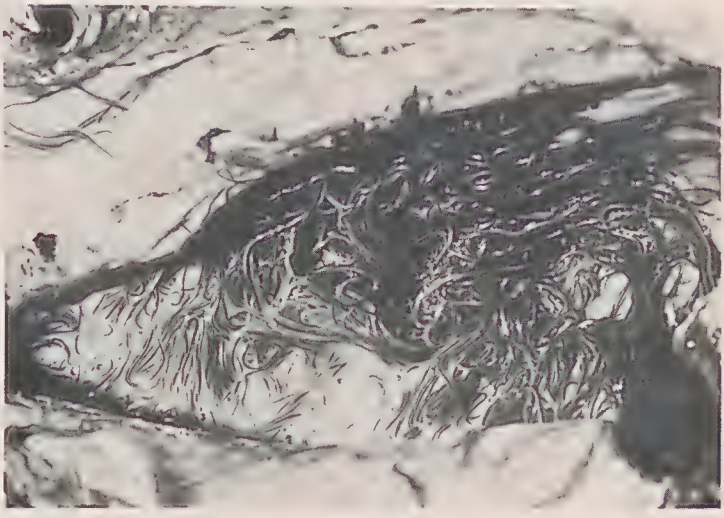

PLATE 5 - *Stenurus* nematodes in middle ear cavity of Pilot Whale (No.22). Photo: T.J. McManus.

The stomachs of two whales contained beaks of squid or cuttlefish, and eye lenses and otoliths of unidentified fish and/or cephalopods. Results of chemical analyses of organs and tissues are given in Appendix 2.

Macquarie Harbour, Strahan, 7 January 1982 (No.27)

A mass stranding of 51 animals. The whales appeared to have become "lost" in the network of shallow channels in the harbour. They remained buoyant most of the time and were still partially submerged when periodically stuck on sand bars. Initially the herd was semi-stranded on a sand bar known as Pelican Spit, 2 km inside the harbour entrance. During the following three days various attempts were made to return the whales to deeper waters in the harbour channels and encourage them to swim out through the harbour mouth. The weather was cool with frequent rain and drizzle which aided the survival of most of the whales.

They seemed generally normal and healthy but were reluctant to move away from a large male which was swimming feebly and appeared weak. One of the ruses employed to coax the whales into deeper water was to tow the sick male and two other bulls by their tailstocks in the hope that the herd would follow. Although this was partially successful it was not until two of the bulls died that the herd became amenable to guidance. On the third day, the herd finally followed a large male being towed backwards for 4 km towards and through the entrance to Macquarie Harbour. When this animal drowned, the porpoising survivors swam past it and continued out to sea.

In the course of events, blood samples were collected via the lateral tail fluke vein from one immature and four mature female whales. These showed slightly elevated levels of haemoglobin, packed cell volume and blood urea nitrogen compared with other normal eutherians, consistent with the effects of dehydration after two days of alternate partial stranding and aimless swimming in the absence of food. Four out of five creatine phosphokinase estimations of between 140 and 160 units per ml were considered normal, but the fifth from a distressed heavily pregnant female was 660 units, suggestive of muscle damage.

Only one of the dead males was autopsied. It was a large mature animal 4.85 m long. In contrast with the situation at Falmouth, only a few *S. globicephalae* nematodes were in its auditory system. Further details are listed in Appendix 1.

The success of the rescue operation was due to the well organised efforts of government officers and volunteers, co-ordinated by the National Parks and Wildlife Service. It was the first time that the Service's rescue contingency plan, drawn up following the Falmouth stranding (No.22), was implemented for a mass stranding.

Howells Point, Maria Island, 14 January 1983 (No.40)

A single animal which had been dead for two or three days when found and assumed to have been washed up dead. It was an adult female, 4.35 m in length. Tissue samples were collected for heavy metal analysis, see Appendix 2.

Killer Whale *Orcinus orca*

Sisters Beach, 2 February 1980 (No.9)

This whale came ashore about 6 a.m. Rescue efforts failed due to the rough seas and the animal's bulk. It died that night. The animal was a mature male 6.7 m long and weighed an estimated 10 tonnes. Apart from limited measurements, the only examination was of the tongue in which a single sarcocyst was detected.

It is the first recorded stranding of a Killer Whale on Tasmanian shores since 1868 (Guiler 1978) although the species is not uncommon around the coast. Between 1980 and 1982 groups of up to 20 have been regularly observed during the period September-December off the southeastern continental shelf, where they interfered with a newly established long-line fishery. A group of 15 was seen by an abalone diver near the Actaeon Islands on 31 January 1983, another group of three was seen by a squid fisherman in the Derwent River not far from Hobart on the night of 3 February 1983.

Common Dolphin *Delphinus delphis*

Shelley Beach, Orford, 25 October 1977
The animal was freshly dead when found but was not closely examined.

Adventure Bay, South Bruny Island, June 1978 (No.4)
This animal was decomposing when found and not further examined.

Little Taylors Bay, South Bruny Island, about 9 March 1982 (No.32)
Two animals, both about 2 m, dead for approximately two days when found. The skulls were collected and retained by the National Parks and Wildlife Service, Hobart.

Ralphs Bay, South Arm, 4 February 1983 (No.45)
A mass stranding, rare for this species, involving 15 animals. As a result of good organisation and rescue equipment (refer stranding number 36) most of the dolphins were rescued within 3½ hours from the initial alert.

The dolphins were divided into two groups, three adult individuals at South Arm Neck and eight adults and four young about 2 km further on, towards the South Arm township. The first group was transported to deep water at South Arm and swam off uneventfully. Of the second group, two small calves and one adult were dead and another adult and calf died shortly afterwards. The others were released together at South Arm and swam away. The surviving calf appeared to recognise its mother, as it swam straight to one of the adults, touched its nose and then continued to swim closely beside her.

The three adults of the first group were neither sexed or measured. Of the second group, all the dolphins rescued were females. Two mature females died, but the three calves which died were all males. Samples from the dead dolphins were taken for analysis and all animals in the second group were measured.

Although the tidal mudflats of the South Arm area are a hazard to dolphins as indicated in the Discussion, it is noteworthy that a squid fisherman observed three Killer Whales hunting dolphins in the Derwent River not far from the entrance to Ralphs Bay on the night before the stranding.

Bottlenosed Dolphin *Tursiops truncatus*

Two Mile Beach, Dunalley, 18/19 February 1975
Two adult dolphins among 200 Pilot Whales (Guiler 1978) and overlooked at the time.

Ralphs Bay, South Arm, 10 September 1977
A single animal, identified but not closely examined.

Adventure Bay, South Bruny Island, 27 April 1978 (No.3)
A single animal, identified but not closely examined.

Pittwater, Midway Point, 1 November 1978 (No.6)
Two dolphins stranded high and dry by receding "spring" tide on the extensive mudflats of Five Mile Beach. They were an adult female and her calf, successfully released together at Lauderdale about 8 hours later.

Ralphs Bay, South Arm, 30 September 1980 (No.12)
First observed at about 5 a.m. A mother and her calf were hopelessly stranded on extensive mudflats and were successfully released at South Arm jetty at 9.30 a.m.

Riedle Bay, Maria Island, January 1981 (No.16)
Three decomposing carcasses found in February 1981 at the northern end of the island's isthmus, on the ocean side.

Eaglehawk Neck, Tasman Peninsula, January/February 1981 (No.18)
When discovered this animal had been dead for at least two weeks and was badly decomposed. No measurements were taken and its sex could not be determined.

Ocean Beach, Strahan, 8 January 1982 (No.28)
An adult female in good condition which swam away five minutes after being returned to the water, 24 hours after stranding in a shallow tidal pool. Overnight rain aided the animal's survival.

Gorringes Beach, South Arm, about 1 April 1982 (No.33)
A male found dead on extensive tidal flats in the same general vicinity as another stranding in May 1964 (Guiler 1978) and from where a mother and calf were rescued on 30 September 1980 (stranding number 12).

Pittwater, Midway Point, 1 October 1982 (No.36)
Virtually the same site as the 1978 stranding of this species (stranding number 6). Pittwater is a large shallow bay with extensive tidal mudflats similar to the South Arm area where strandings are also common. A 2.55 m male and a 2.70 m female were found in good condition without blisters or visible ailments.

A feature of this stranding was that it gave National Parks and Wildlife Service personnel the first opportunity to test newly acquired rescue equipment, evolved as a result of attempts to rescue Pilot Whales at Falmouth (stranding number 22). A special rescue sheet made from non-porous material (PVC "Ripstop"), glided over the wet sand and a "net" of ropes fixed to its edges easily transformed it from a sledge to a stretcher. As a result both animals were released without incident into the surf at Seven Mile Beach township a few kilometres away, less than three hours after the original report of the stranding was received. By contrast the 1978 rescue (stranding number 6) took nearly eight hours.

Seven Mile Beach, about 24 January 1983 (No.42)
This animal was found dead on the seaward side of the long sandspit which forms Pittwater, the site of previous strandings of the species (strandings number 6 and 36). It was a 3.4 m male, but further examination was not possible as the carcass had started to decompose when discovered.

DISCUSSION

There has been a significant increase in the number of recorded strandings in recent years. During the 5½ years to 31 May 1983 there were 46 incidents, compared to 28 in the preceding 5½ years and 106 for the whole of the recorded history of Tasmania as reported by Guiler (1978). It is likely that the increase is a result of improved reporting, rather than a greater abundance of whales or higher frequency of strandings.

In Tasmania, a mass stranding of Pilot Whales at Falmouth in 1981 led to the formulation of a contingency plan under which the National Parks and Wildlife Service co-ordinates rescue operations and scientific investigations at strandings. Information flow to the media has been an important part of the contingency plan and local media coverage of strandings, even if they were of an unspectacular nature, has been frequent and excellent. This has served to heighten an already growing public awareness of whales. Dead whales, which probably would have gone unrecorded in the past, are now often reported on the day they are found. One important benefit is that chances of discovery of rare species are improved. The data presented add two species new to Tasmania, Sei Whale and Southern Bottlenosed Whale, to the number previously cited by Guiler (1978) and add significantly to scanty information on other species.

Greater mobility of people and improved access to beaches are likely to be major contributing reasons for the increase in recorded strandings. Obviously, if few people visit a particular location, a stranded whale may well go unrecorded as remains can wash away or become buried very quickly by wave or wind action. Examination of table 1 shows that all stranding dates except seven (numbers 3, 4, 5, 13, 14, 24 and 46) fall within the summer holidays or other school vacations when there are more people in coastal areas. During the last decade ownership of trail bikes and four-wheel drive vehicles has increased. Beaches which were remote and inaccessible ten years ago are now visited frequently.

Only one stranding was reported from the densely populated north and northwest coasts to the east of Stanley. Of the more than 100 previous strandings (Guiler 1978) only 10 occurred along that part of the Tasmanian coast. As beaches and foreshores there would be visited at least as frequently as other coastal areas, it must be concluded that whale strandings between Wynyard and Bridport are rare events. A possible explanation is that the shallow waters of Bass Strait adjacent to the central north coast are not part of the migratory routes of whales.

Reference to figure 1 shows that three locations have had a high number of strandings. These are Perkins Bay (Stanley), Storm Bay (Hobart) and Macquarie Harbour and Ocean Beach near Strahan.

Whales moving south past King Island may find themselves in the western end of Bass Strait. Whilst attempting to leave the area, they face a formidable hazard. The Circular Head Peninsula, with the town of Stanley, juts out into the Strait for a distance of 10 km. Perkins Bay to the west is a large but shallow body of water with shoals, sandbars and channels, semi-enclosed by the peninsula and Perkins and Robbins Islands. Tidal flows are very rapid. The chances of whales employing sonar becoming confused or whales simply being left by a fast receding tide, appear to be high. The latter hazard can be exacerbated if a strong northwesterly wind coincides with an incoming tide and then drops or changes direction, as happened in the case of stranding number 34. Perkins Bay has been described as a "whale cemetery" by Scott (1942). Of 65 strandings in places with more than one stranding between 1945 and 1977, 12 (18%) occurred here (Guiler 1978). Of the 46 recent strandings 5 (10%) happened in this relatively small part of the coast.

In the south, a similar hazard is present in Storm Bay, which incorporates the Derwent estuary, Ralphs Bay, Frederick Henry Bay, Pittwater and Norfolk Bay. Storm Bay is a large body of water semi-enclosed by the Tasmanian mainland, North Bruny Island and the Tasman Peninsula. This topographical pattern is repeated many times on a smaller scale within the area. Many of the bays are characterised by extensive tidal flats. Of the 46 recent strandings, 9 (20%) occurred here. Most of these involved dolphins left stranded by the outgoing tide.

A further 5 (10%) of the recent strandings occurred on the west coast near Strahan where Cape Sorell and the southern section of Ocean Beach form a funnel leading into Macquarie Harbour. Rounsevell *et al.* (1981) described this section of coast as treacherous to whales due to the topographical features of the coast and sea bottom.

Together, the above locations occupy less than 10% of the Tasmanian coast but account for about 40% of recent strandings. This suggests that, at least in Tasmania, whale trap situations leading to navigational error or the simple misfortune of being left stranded by a fast receding tide, are of significance in causing or contributing to strandings. This is contrary to the findings of Sergeant (1982) who concluded that animals about to strand are in a passive, moribund state drifting to the coastline by currents and who discounted external factors such as coastal configuration.

The "spring" tides caused by gravitational forces at full and new moon, being more extreme with consequently faster tidal flow rates, are likely to exacerbate or even create the hazards described above. Although only 13 of the recent strandings occurred at times of peak tides, this aspect bears further investigation in future as 10 of these strandings happened in summer when such tides are generally stronger than in other seasons.

As elsewhere, herd cohesion in the gregarious toothed whales (causing the herd to beach *en masse* in response to distress signals emitted by stranded individuals) is believed to have been a factor in at least some mass strandings in Tasmania. In the case of the herd of Pilot Whales entrapped in Macquarie Harbour (number 27), herd cohesion was successfully used in the rescue.

Pathological investigation has only been possible in a relatively small number of the strandings reported here. However, indications to date are that disease has not been a significant factor. Auditory parasitism can compromise navigational abilities under

adverse conditions (Dailey & Walker 1978). This appears to have been a significant contributory factor in the mass stranding of Pilot Whales at Falmouth (number 22), where the mature males examined (presumed to have been the herd leaders) were found to be severely affected. On the other hand, no significant infestation was found in the Pilot Whales at Macquarie Harbour (number 27) where topographical factors provide a satisfactory explanation for the stranding.

Observations in Tasmania to date do not lend credence to hypotheses (Cordes 1982) such as "attempting to negotiate ancestral pathways now above the waterline", or "an instinctive tendency to return to land when in distress" or even "mass suicide". Human observers have long been puzzled by the apparent deliberateness of whale behaviour at mass strandings, especially the observed tendency of rescued whales to return to the beach. However, there are a number of quite satisfactory explanations for such observed behaviour, including herd cohesion and muscle cramp. The whales rescued at Falmouth (number 22) did not have a tendency to return to the beach, probably because they were unable to communicate with the remaining live whales which were far from the waterline at the time of rescue. Observations on rescued dolphins which had been lying on one flipper for a long time showed a strong tendency to list and swim in circles which led them back to the beach. Once rescuers held these animals in the water for five or ten minutes prior to release, such problems were not experienced. The theory that sick or dying whales may have a tendency to "return" to land to avoid drowning does not stand up to scrutiny. If it were correct, strandings would occur far more frequently.

A great deal more research will be necessary before all strandings can be confidently explained. Tasmania appears to be in an excellent position for such work due to the high frequency of strandings. The Tasmanian contingency plan provides a suitable and increasingly effective framework for co-ordinated research by biologists, pathologists and others. An understanding of the causes of stranding is not only of academic interest, but essential to the success of future rescue operations.

The questions of rescue, euthanasia and disposal of stranded whales are vexed ones also in need of considerably more study.

At Macquarie Harbour and Falmouth, as well as a number of rescues in the Hobart area, whales were returned to sea and were seen to swim away. The animals involved were not marked and their eventual fate can only be speculated upon. At Falmouth (number 22) evidence suggests that at least some of the "rescued" Pilot Whales did not survive and similar doubts were raised after the departure of Sperm Whales (number 17) from the entrance to Macquarie Harbour. On the other hand, the rescue of Pilot Whales (number 27) from Macquarie Harbour and a number of dolphin rescues near Hobart (numbers 6, 12, 36 and 45) were not followed by reports of subsequent strandings and these are likely to have been successful.

The National Contingency Plan for Cetacean Strandings (Anderson 1982) states that its primary objective is to return stranded cetaceans to sea. In Tasmania, the actions of authorities are in line with this objective and the State Government has provided a special contingency fund for the purpose. If, as suggested by Geraci & St Aubin (1979), survival rate is low, the present heavy use of resources may not be justified in certain instances. Further investigations, and above all more experience, are necessary to enable the formulation of firm guidelines which can be enforced by the National Parks and Wildlife Service. These guidelines should indicate when a substantial effort to rehabilitate the whales is warranted or when nothing should be done. They should include appropriate rescue methods, marking, euthanasia and disposal.

Euthanasia is an emotive issue, but experienced researchers agree that it is indicated where the continued survival of individuals prejudices the survival of the herd or when it is physically impossible to return the whales to sea (Geraci & St Aubin 1979, Mead pers. comm., Cawthorn pers. comm.). Considerable research is needed into practical and acceptable methods of euthanasia for different species (Munday 1983).

Disposal of carcasses sometimes constitutes a major problem, especially if large animals or large numbers are involved. To date, deep burial has been the most satisfactory method and modern heavy machines such as bulldozers, backhoes and logskidders have all been utilised for this purpose. It has been suggested locally that carcasses should be used for meat-meal or pet food; however, the level of mercury in the flesh (Appendix 1) makes such use undesirable. Indeed, it will be noted that the Pilot Whale washed up on Maria Island (number 40) had a mercury level in its subcutaneous muscle of 6.2 ppm. The maximum safe limit for human consumption of shark flesh, prescribed by Health Departments in Tasmania and South Australia is 1 ppm, and 0.5 ppm in the other Australian States.

A hitherto ignored factor likely to influence the recuperation of cetaceans returned to sea is external rhabdomyolysis, also known as "capture myopathy". Regardless of continuing improvements in methods and equipment used at strandings, considerable manhandling will almost always be necessary. Studies into the possible effects of this are therefore essential (Colgrove 1978).

Positive physical identification of every cetacean at a stranding has been widely recognised as an essential procedure and has been incorporated into the National Contingency Plan for Cetacean Strandings (Anderson 1982). It should be implemented in Tasmania. Collection of data other than mere statistics must also receive greater attention. This should include a more professional approach to photographic recording, which should be an integral part of every investigation.

Only by more precise analysis of observed and recorded data will scientific knowledge be enhanced sufficiently to permit improved management of cetacean strandings.

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APPENDIX 1

PATHOLOGICAL, PARASITOLOGICAL AND MICROBIOLOGICAL FINDINGS

Stranding No.	9	22	22	22	22	22	22	23	26	27	31	
Species	Oo	Gm	Gm	Gm	Gm	Gm	Gm	Cm	Ml	Gm	Pm	*O.orca, G.malaena, C.marginata, M. layardi, P. macrocephalus.*
Length	6.7	5.4	5.45	2.6				6.45	4.53	4.85	10.4	metres
Sex	♂	♂	♂	♀	♂	♀	♂	♀	♀	♂	♀	
Age	M	M	M	J	M	M	M	M	M	M	M	M = mature J = juvenile
Lungs:												
Inhalation of seawater		x	x	x				x		x	x	
Parasites		x	-	-						x		Unidentified
Bacteria		x[1,2]	-	-								[1]=*Streptococcus* sp. [2]=*Pseudomonas* sp.
Auditory Canals:		L	R	-	L	R	L	L		-	few	*Stenurus globicephalae*
Parasites		1600	1940		1140	2900	124	4200				
Bacteria		x	x	-				x				*Streptococcus* sp.
Inflammation		x	x	-				x				
Stomach:												
Parasites		x	x							x		*Anisakis simplex*
Intestines:												
Parasites		x[1]						x[2]		x[3]		[1]Unidentified cestodes [2]*Ogmogaster* sp. [3]*Bolbosoma capitatum*
Blubber:												
Parasites		x								x		Larval *Phyllobothrium delphini*
Muscle:												
Parasites	x	x	-	-	x		x	-	-		x	Sarcocysts

APPENDIX 2

CHEMICAL ANALYSES OF TISSUES

STRANDING No.	(22)	(22)	(22)	(22)	(22)	(22)	(26)	(27)	(31)	(34)	(35)	(40)	(43)	
SPECIES	G.m.	G.m.	G.m.	G.m.	G.m.	G.m.	M.l.	G.m.	P.m.	C.m.	C.m.	G.m.	C.m.	*G. melaena, M. layardi, P. macrocephalus, C. marginata*
LENGTH	5.4m	5.45m	2.6m				4.53m	4.85	10.4m	6.0m	6.09m	4.35m	5.0m	
SEX	♂	♂	♀	♂	♀	♂	♀	♂	♀	♀	♂	♀	♀	
AGE	M	M	J	M	M	M	M	M	M	M	M	M	M	M = Mature J = Juvenile
LIVER														
Pb							-	-						
Cd							-	13						
Cu							2.7	5.6						
Zn							10.0	31						values in ppm
KIDNEY														
Pb								-						
Cd								12						
Cu								3.0						
Zn								22						
BLUBBER														
Dieldrin	-	-	-	-	0.2	-	0.1			t	t	t	0.1	t = trace - less than 0.05 ppm
D.D.T.	0.4	0.4	1.3	0.3	0.2	0.5	0.3	0.8		t	t	t	0.5	
D.D.E.	0.5	0.5	2.8	0.5	0.4	0.9	0.3	0.5		t	t		0.5	values in ppm
D.D.D.										t			0.1	
H.C.B.	t	t	t	-	-	t					t	t	0.1	
Lindane												-	t	
BRAIN														
Dieldrin	t													
D.D.T.	-													
D.D.E.	t													
H.C.B.								-						
MUSCLE														
Hg	1.89		0.29	0.31		1.29	1.17	1.66	0.61		0.03	6.2		values in ppm

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THE STRATIGRAPHY OF A LATE PALAEOZOIC BOREHOLE SECTION AT DOUGLAS RIVER, EASTERN TASMANIA: A SYNTHESIS OF MARINE MACRO-INVERTEBRATE AND PALYNOLOGICAL DATA

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(with one table, four text-figures and three plates)

ABSTRACT

CALVER, C.R., CLARKE, M.J. and TRUSWELL, E.M., 1984 (31 viii): The stratigraphy of a Late Palaeozoic borehole section at Douglas River, eastern Tasmania: a synthesis of marine macro-invertebrate and palynological data. *Pap. Proc. R. Soc. Tasm.*, 118: 137-161, pls 1-3. ISSN 0080-4703. Department of Mines, Rosny Park, Tasmania and Bureau of Mineral Resources, Canberra, A.C.T.

A section 236.8 m in thickness of Late Palaeozoic (Late Carboniferous-Permian) rocks of the Lower Parmeener Super-Group was encountered in a borehole at Douglas River, eastern Tasmania. Lithological, marine macro-invertebrate and palynological data are documented and collated. The section displays many similarities with sequences elsewhere in eastern and northeastern Tasmania, but is unusual in the development of rocks (including *Tasmanites* shale) as old as Early Tamarian. This occurrence may indicate a narrow, but significant east-west breaching of the land barrier which persisted throughout the Tamarian over most of eastern and northeastern Tasmania. Acritarch swarms coeval with sedimentation occur at intervals, whereas other acritarchs may be derived from earlier Palaeozoic rocks. The Tasmanian Late Permian palynofloras lack diversity and resemble those from the Transantarctic Mountains, Antarctica, rather than those from elsewhere in eastern Australia.

INTRODUCTION

In 1978 a fully cored diamond borehole (NQ_3 diameter 45 mm) was drilled at Douglas River (fig. 1) as part of a programme to provide control for the interpretation of a gravity survey related to coal exploration in northeastern Tasmania (Leaman & Richardson 1981). A brief (and somewhat inaccurate) summary log is given therein (Appendix 3, p.72, Hole 045/732). Recently, as an extension of studies on Late Palaeozoic sequences in the adjacent St Marys Quadrangle (Turner, Calver, Castleden & Baillie, in press) and Maria Island (Clarke & Baillie 1981, 1984), Calver completed a detailed lithological log of the hole and recognised the hitherto unknown development of Early Tamarian rocks (including *Tasmanites* shale) in northeastern Tasmania. Clarke then became involved with the marine macro-invertebrate faunas, and samples for palynological analysis were forwarded to E.M. Truswell. The various sections and responsibilities in this communication are allocated along similar lines. Authors are listed alphabetically.

LITHOSTRATIGRAPHY [C.R.C.]

The Douglas River (or Bicheno No.10) borehole was collared in Triassic coal measures and penetrated a continuous and almost complete section of the Lower Parmeener Super-Group before entering a folded and cleaved Siluro-Devonian quartzwacke turbidite sequence of the Mathinna Beds at 333.80 m. A summary graphic log is given (fig. 2). Formal stratigraphic nomenclature is not used for the various flat-lying lithological units; instead the informal terms Lower Marine Sequence, Lower Freshwater Sequence and Upper Marine Sequence are employed.

Late Palaeozoic Borehole Section at Douglas River, Tasmania

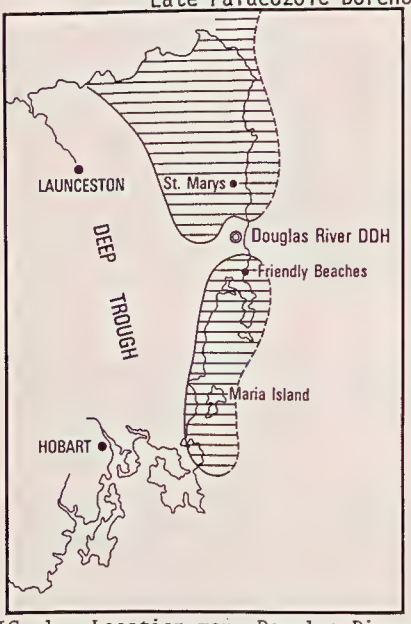

FIG. 1 - Location map, Douglas River borehole, with inferred Early Tamarian palaeogeography. Land areas are horizontally rules.

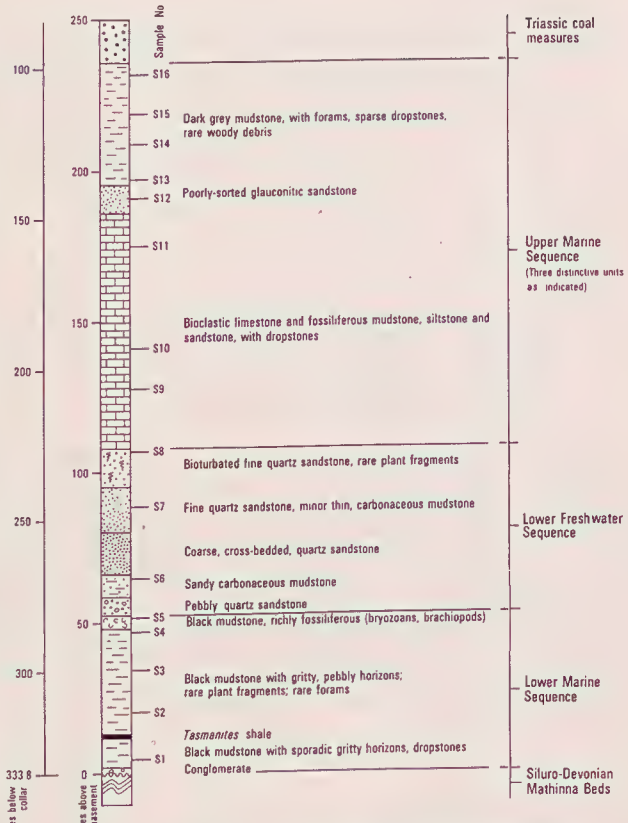

FIG. 2 - Graphic log, Douglas River borehole.

Lower Marine Sequence (51.8 m thick)

The Lower Marine Sequence rests with abrupt unconformity on folded and cleaved Siluro-Devonian quartzwacke turbidite Mathinna Beds. The basal few metres consist of arkosic conglomerate, but for the most part, the Lower Marine Sequence consists of poorly-sorted, dark grey and black mudstone with sporadic sandy and granule horizons. Lonestones are present together with rare plant fragments and forams. *Tasmanites* shale occurs in two seams between 320 and 321.50 m. The uppermost four metres of the Lower Marine Sequence is richly fossiliferous with well-preserved bryozoans, brachiopods and molluscans.

Lower Freshwater Sequence (56.0 m thick)

The Lower Freshwater Sequence consists of five more or less distinct units. At the base, pebbly quartz sandstone is followed by a similar thickness of sandy, carbonaceous mudstone. Then follow three subequal units of coarse-grained, cross-bedded quartz sandstone; fine-grained quartz sandstone with minor, thin, carbonaceous mudstone, thin coals and coal streaks; and bioturbated fine-grained quartz sandstone with rare plant fragments. The overall thickness of 56 m is similar to that of comparable sections in the St Marys Quadrangle, but considerably greater than that of the Boullanger Formation on Maria Island (Clarke & Baillie 1983), and freshwater sequences encountered in recent boreholes in the midlands of Tasmania at The Quoin, Ross, Tunbridge and Bothwell.

Upper Marine Sequence (129.0 m thick)

The Upper Marine Sequence consists of three distinct units. At the base medium- to thick-bedded, pale grey bioclastic limestone is interbedded with subordinate mudstone, siltstone and sandstone. The unit is 78 m thick and lonestones occur throughout. Fossils are abundant. Then follows 10 m of poorly-sorted, pebbly and sparsely fossiliferous glau-

conitic sandstone. The uppermost unit consists of 41 m of dark grey, poorly-sorted mudstone with dispersed granules and sparse lonestones, forams in some abundance at certain horizons, and rare woody debris. The base of the overlying Triassic coal measures sequence is abrupt and disconformable on a regional scale. The Upper Marine Sequence is similar lithologically to comparable sections in the St Marys Quadrangle and elsewhere in northeastern Tasmania, Friendly Beaches and Maria Island.

MARINE MACRO-INVERTEBRATE PALAEONTOLOGY [M.J.C.]

The study of marine macro-invertebrate fossils in small diameter drill core presents certain difficulties. Whereas organisms such as stenoporid bryozoans, and both rugosan and tabulate corals which require thin section preparation, can be reliably identified, larger molluscans and spiriferid and productid brachiopods can be rarely identified with confidence beyond the genus level. In limestone in particular they are not readily separated from the matrix, or the shell exfoliates leaving neither detailed exterior nor interior moulds. Acid cannot be used to produce moulds for subsequent casting. Furthermore, the limited core intersections usually preclude the determination of detailed gross morphology and other critical diagnostic characters. Nevertheless, the overall lithological sequence in the Douglas River borehole (within the Upper Marine Sequence at least) compares very favourably with nearby sections in the St Marys Quadrangle, at Friendly Beaches and Maria Island where large, well-preserved collections have been recently collected and analysed. This factor allows significant and reasonably accurate (although admittedly inferential) conclusions to be made concerning the zonal distributions of the marine macro-invertebrate faunas in the drill core. Zonal allocations are made in accordance with the scheme of Clarke & Banks (1975), Clarke & Farmer (1976), and Clarke (in Clarke & Baillie 1984).

Spiriferids previously ascribed to *Tomiopsis* Benediktova, 1956 are herein referred to *Ambikella* Sahni and Srivastava, 1956, since Benediktova's name is a junior homonym of the mammalian *Tomiopsis* Cope, 1893 (Doescher 1981).

Lower Marine Sequence

Tasmanites shale

Macrofossils were not observed in the *Tasmanites* shale at 321 m. However, the *Tasmanites* shale consistently occupies a position low in the stratigraphic sequence and yields a Stage 2 microflora at all localities where sampled (Truswell 1978, and herein). The *Tasmanites* shale doubtless represents an unique interval when an algal bloom proliferated and accumulated about shorelines in the Tasmania Basin. At Latrobe, where the shale was mined on a substantial scale, a surprisingly varied macrofauna has been obtained. Forms present include *Streptorhynchus* sp.nov., *Strophalosia* sp. nov., *Ambikella* cf. *elongata* (McClung and Armstrong), *Trigonotreta stokesi*, *Pseudosyrinx* sp., *Deltopecten* sp. ex gr. *illawarensis* (Morris), *Etheripecten tenuicollis* (Dana), *Eurydesma hobartensis hobartensis* (Johnston), *Megadesmus pristinus* Runnegar, *Merismopteria* sp., *Phestia darwini* (de Koninck), *Promytilus* sp., *Pyramus laevis* (Sowerby), *Schizodus australis* (Runnegar), *Stutchburia* sp., *Keeneia twelvetreesi* Dun (the type locality - see Dun 1913), and *Peruvispira* sp. The presence of *Streptorhynchus* sp.nov., *Strophalosia* sp. nov., *Ambikella* cf. *elongata* and *Megadesmus pristinus* indicates an Early Tamarian (Faunizone 1) age.

Black mudstone

A rich, well-preserved fauna occurs in the uppermost 4 m of the Lower Marine Sequence. Forms present include *Strophalosia subcircularis* Clarke, *Trigonotreta stokesi* Koenig, *Deltopecten illawarensis* (Morris), *Etheripecten* sp., *Eurydesma* sp., *Stenopora tasmaniensis* Lonsdale and fenestellids. *Strophalosia* and the bryozoans occur in profusion and in life orientation. The presence of *S. subcircularis*, *T. stokesi* and *S. tasmaniensis* unequivocally indicates a Tamarian age. The presence of *S. subcircularis* rather than *Strophalosia* sp. nov. (a form with a markedly raised ventral adductor platform) and the absence of *Streptorhynchus* sp. nov. precludes an Early Tamarian (Faunizone 1) age, and the absence of *Sulciplica* sp. nov. and *Notospirifer* sp. suggests that the fauna is not as young as Late Tamarian (Faunizone 3) age. The fauna is therefore assigned to the Middle Tamarian

(Faunizone 2). Palynological evidence (see later) indicates that the Late Tamarian is represented within the lower parts of the Lower Freshwater Sequence.

Upper Marine Sequence

Limestone

The thick limestone unit is richly fossiliferous. Forms identified include *Euryphyllum* sp., *Gertholites* [*Thamnopora*] *wilkinsoni* (Etheridge), *Cancrinella farleyensis* (Etheridge and Dun), *Terrakea* sp., *Wyndhamia dalwoodensis* Booker, *Ambikella* spp., fasciculate spiriferids including *Trigonotreta hobartensis* (Brown), *Sulciplica* spp. including *S. tasmaniensis* (Morris), *Deltopecten limaeformis* (Morris), *Etheripecten* spp., *Eurydesma* sp., *Streblopteria* sp., *Stenopora* spp. and fenestellids. Intersections of a coarsely-spinose productid completely cover the core surface at 214 m and 182 m. These are almost certainly the large aulostegid *Taeniothaerus subquadratus* (Morris), but the identification is inferential. *Wyndhamia dalwoodensis*, spiriferids, bryozoans and *Deltopecten* are the commonest elements, and crinoidal debris is abundant. The tabulate coral *Gertholites wilkinsoni* is reasonably common above 179 m in more argillaceous limestone.

The main limestone unit is lithologically similar to limestone developments in the Mt Elephant area near St Marys, the Peter Limestone at Friendly Beaches (Banks 1955) and the Counsel Creek Formation on Maria Island (Clarke & Baillie 1984) and all are of the same order of thickness. *Cancrinella farleyensis*, *Anidanthus springsurensis* (Booker) and *Taeniothaerus subquadratus* are characteristic occurrences in the surface developments. *Gertholites wilkinsoni* occurs abundantly in the upper parts of the Counsel Creek Formation.

The stratotype for the Bernacchian Stage is on Maria Island and the detailed stratigraphic palaeontology has been recently described (Clarke, in Clarke & Baillie 1984). The sequence at Douglas River differs from the stratotype in that there is no lithological equivalent of the marine Skipping Ridge Formation (= Early Bernacchian) which occurs between the Boullanger Formation (= Lower Freshwater Sequence) and the Counsel Creek Formation. This may be the result of facies change, but this is considered to be unlikely since the linoproductid *Terrakea* occurs from 221 m upwards; *Terrakea* is unknown before the Late Bernacchian in Tasmania. The major part of the limestone at Douglas River is therefore referred to the Late Bernacchian *Taeniothaerus subquadratus* Zone. Palynological data (see later) indicate that the Early Bernacchian is represented (at least in part) within the upper parts of the Lower Freshwater Sequence. A probable hiatus occurs between the Early and Late Bernacchian at Douglas River. On Maria Island the uppermost 12 m of the Counsel Creek Formation belongs with the Early Lymingtonian. A similar biostratigraphy is inferred at Douglas River, but proof is lacking.

Glauconitic sandstone

The glauconitic sandstone unit contains much broken shell debris but little can be positively identified. At 149 m is a large *Ambikella* with a very low fold probably belonging with the *brevis-undulosa-isbelli* plexus, and part of the large alate species *Sulciplica transversa* Waterhouse occurs at 142 m.

The glauconitic sequence at Douglas River is similar to, and occupies the same stratigraphic position as the Marra Formation on Maria Island, and developments of glauconitic sandstone at Friendly Beaches and elsewhere in northeastern Tasmania. Such sequences are always thin and attenuated, and probably represent discontinuous sedimentation. At Friendly Beaches and on Maria Island faunas range in age from Early to late Middle Lymingtonian (Clarke, in Clarke & Baillie 1984). *Sulciplica transversa* is unknown below the Middle Lymingtonian in Tasmania.

Upper mudstone

No macro-invertebrates were observed in the uppermost mudstone unit although forams are abundant at certain levels together with some woody debris.

The uppermost mudstone unit is similar to, and occupies the same stratigraphic posi-

tion as the Toarra Formation on Maria Island and similar developments elsewhere in north-eastern Tasmania. These deposits are thought to have accumulated in a shallow lagoonal embayment under estuarine conditions (Banks 1962, p.210). Normal salinities returned only briefly in a series of short-lived incursions from the south and southeast. On Maria Island (and elsewhere) a thin productid bed yields *Echinalosia ovalis* (Maxwell), *Terrakea brachythaera* (Morris) and other fossils which prove a Late Lymingtonian (Faunizone 10) age. The Douglas River area is beyond the limits of these marine incursions.

PALYNOLOGY [E.M.T.]

Palynological investigations of Tasmanian Permian sequences undertaken in the nineteenth and twentieth centuries were reviewed by Truswell (1978), in the course of a study of the older parts of the Lower Parmeener Super-Group. From that review it is evident that the palynology of Tasmanian sequences younger than Early Permian has received little attention. Previous studies of younger Permian intervals include the examination by Dulhunty & Dulhunty (1949) of microspores from coals at Pelion, Cradoc and Preolenna, and reports by Balme (in Jennings 1963, in Spry & Banks 1962, and in Banks & Naqvi 1967) of the spore and pollen content of samples from the Cygnet Coal Measures at Cygnet, the Henty River, Pelion Range, Sky Farm near Hobart, and from the Jackey Shale at Western Bluff. Species lists were given in Banks & Naqvi (1967, p.21) and the palynomorphs listed there were assigned to Balme's (1964) *Dulhuntyispora* Assemblage. A Kazanian to Tatarian age was suggested because of apparent similarities to assemblages from the Liveringa Formation of Western Australia; similarities with assemblages from the Newcastle Coal Measures also drew comment. No mention was made of the absence of the nominate form *Dulhuntyispora* from the Tasmanian species lists, but Balme (in Jennings 1963) did comment on the predominance of long-ranging Permian taxa in the Jackey Shale, and hinted at palaeogeographic differences between Tasmanian floras and those of the mainland.

The study of sections cored at Golden Valley near Poatina, and Beaconsfield, which were examined palynologically by Truswell (1978), afforded an opportunity to relate a palynological zonation (Kemp *et al.* 1977) to the faunal assemblages of Clarke & Banks (1975). From that correlative study, it became apparent that Faunizone 1 is associated with palynological assemblages referred to Stage 2 and Substage 3a, and Faunizones 2-3 are associated with Substage 3a. Glacial sediments at the base of the Parmeener Super-Group, which usually lack invertebrates, were shown to be associated with Stage 1 and Stage 2 assemblages; the *Tasmanites* oil shale with Stage 2. The Mersey Coal Measures, at all the localities at which these were sampled, contained palynofloras referable to Substage 3b.

The Douglas River borehole sequence examined here afforded the opportunity to establish the palynomorph content for the intervals encompassing Faunizones 1 to 10. The opportunity for clear faunal and floral correlation was marred by generally poor preservation of palynomorphs. In the marine intervals spores and pollen are much fragmented, probably as a result of transportation processes. In both marine and non-marine parts of the sampled sequence palynomorph walls have been ruptured and damaged by pyrite crystallization. In some cases, especially with the fragile walls of saccate pollen grains, this process has been severe enough to make identification to species level difficult.

The biostratographic scheme used here is based on the system of palynological "Stages" which Evans (1969) consolidated from his earlier work, and which has subsequently been subdivided and modified by a number of workers. Summaries of the development of the "Stage" system, and of its application to the Permo-Carboniferous of eastern Australia, are given in Kemp *et al.* (1977) and in Price (1983). In their present form, the stages, and their substages, are in fact interval zones, each unit representing the interval between horizons defined by the first appearance in time of selected taxa. In some cases the nominate taxa form part of a clearly identifiable morphologic lineage. Price (1983) has provided a formal nomenclature for the interval zones. The biostratigraphic bases for these rest on sections in the Cooper, Bowen and Galilee Basins. Their application in south-eastern Australia remains to be fully tested, so for the purposes of this study the stages of Evans (1969) as defined in Kemp *et al.* (1977) have been applied, and probable correlations with the formalized interval zones indicated where appropriate.

Ranges of stratigraphically important taxa are indicated in figure 3, together with the position of palynological stage boundaries in the Douglas River section. The relative frequencies of selected species or species groups are shown in figure 4, for those intervals where preservation was good enough for counts to be made. The range chart (table 1) shows the distribution of all taxa identified.

From the base of the Douglas River sequence, the palynological units, and their lithological extent, are as follows:

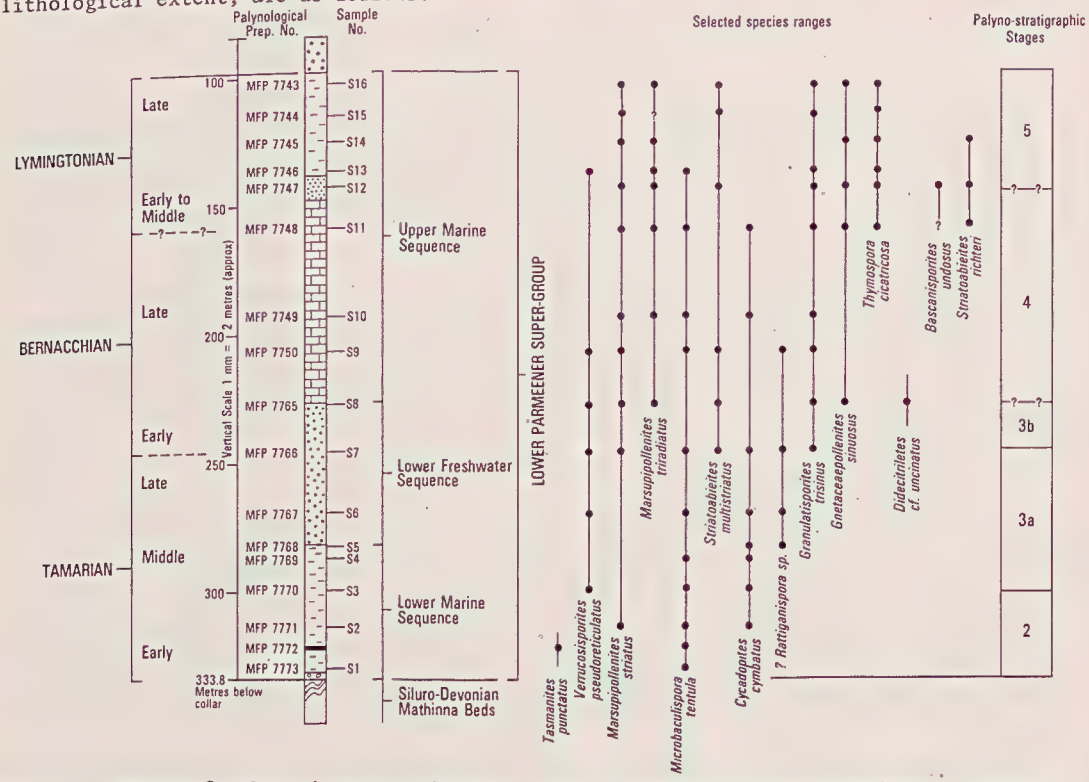

FIG. 3 - Ranges of selected spore and pollen species in Douglas River borehole. Boundaries of palynostratigraphic stages after Kemp *et al.* (1977) shown in right-hand column, and Tasmanian stage nomenclature based on marine macro-invertebrates shown in left-hand column.

Stage 2

Three cores from the lower part of the Lower Marine Sequence can be referred to Stage 2 - these are from depths of 328 m, 321 m (from the *Tasmanites* shale) and 313 m. Preservation of palynomorphs is extremely poor at all sampled levels, and diversity is low. Only the sample at 313 m was suitable for palynomorph counts to be made: this sample, like the others from Stage 2, showed a dominance of monosaccate pollen, mostly referable to *Plicatipollenites*, with less common *Potonieisporites*, and with a frequency of *Microbaculispora tentula* Tiwari of 18 per cent. This high frequency of *M. tentula* is characteristic elsewhere of upper Stage 2; the presence of *Marsupipollenites striatus* (Balme & Hennelly) and *Cycadopites cymbatus* (Balme & Hennelly) is in accord with an upper Stage 2 attribution. For the samples from 321 m and 328 m, preservation is too poor to identify subdivisions finer than Stage 2. The *Tasmanites* shale yielded a characteristically impoverished palynoflora; residues are dominated by fragments of the presumed green alga *Tasmanites punctatus* Newton, which obscures other forms; the rare pollen and spores are much fragmented and thinned.

Spores and pollen	Preparation and depth	MFP	328 m	321 m	313 m	299 m	287 m	282 m	269 m	245 m	227 m	211 m	193 m	159 m	143 m	137 m	125 m	115 m	102 m
			7773	7772	7771	7770	7769	7768	7767	7766	7765	7750	7749	7748	7747	7746	7745	7744	7743
Apiculatisporis cornutus (Balme & Henn)											X					X		X	X
A. sp. cf. *A. cornutus* (Balme & Henn)														X					
Barakarites rotatus (Balme & Henn)											X								
Bascanisporites sp. cf. *B. undosus* Balme & Henn														X	X				
Brevitriletes sp. cf. *B. levis* (Balme & Henn)														X					
Caheniasaccites sp.			X																
Camptotriletes biornatus Balme & Henn											X								
Cannanoropollis sp.			X								X								
Cycadopites cymbatus (Balme & Henn)				X	X	X	X	X	X	X			X	X					
Didecitriletes ecericiana (Anderson)											X								
Didecitriletes sp. cf. *D. uncinatus* (Balme & Henn)											X								
Florinites eremus Balme & Henn														X					
Gnetaceaepollenites sinuosus (Balme & Henn)											X			X	X	X	X		X
Granulatisporites micronodosus Balme & Henn				X							X	X					X		
Granulatisporites sp. cf. *G. micronodosus* Balme & Henn										X	X				X	X	X	X	X
Granulatisporites trisinus Balme & Henn										X	X	X	X	X	X	X		X	X
Horriditriletes ramosus (Balme & Henn)			X	X	X					X	X								
Indotriradites splendens (Balme & Henn)											X			X					
Indotriradites sp.										X									
'Jugasporites' sp.											X								
Leiotriletes directus Balme & Henn							X		X	X					X	X			X
Limbosporites sp. cf. *L. balmei* Foster														X					
Limitisporites sp. cf. *L. rectus* Leschik										X	X								
Marsupipollenites striatus (Balme & Henn)					X					X	X	X	X	X	X	X	X	X	X
Marsupipollenites triradiatus Balme & Henn											X		X	X	X	X	X		X
Microbaculispora tentula Tiwari			X		X	X	X		X	X		X	X	X		X			
Neoraistrickia gracilis Foster											X				X				
Platysaccus leschikii Hart										X	X	X		X	X		X		
Plicatipollenites densus Srivastava			X		X	X	X	X	X	X				X			X		
Plicatipollenites gondwanensis (Balme & Henn)																	X		
Plicatipollenites spp.			X	X	X	X	X	X	X	X	X			X	X	X	X	X	X
Polypodiisporites leopardus (Balme & Henn)														X	X		X		X
Potonieisporites methoris (Hart)													X	X					
Potonieisporites spp.				X		X								X		X			
Protohaploxypinus amplus (Balme & Henn)										X	X	X	X		X		X		X
Protohaploxypinus limpidus (Balme & Henn)										X	X		X	X		X	X	X	X
Pteruchipollenites sp.										X	X			X	X				
Punctatisporites gretensis Balme & Henn				X	X				X	X									
?Rattiganispora sp.								X	X	X	X		X						
Retusotriletes diversiformis Balme & Henn										X				X					
Scheuringipollenites maximus (Hart)												X		X		X			
Scheuringipollenites ovatus (Balme & Henn)												X		X	X	X	X	X	X
Striatoabieites multistriatus (Balme & Henn)											X	X	X		X		X	X	X
Striatoabietites richteri (Klaus)															X	X			
Striatoabieites sp.					X												X		
Striatopodocarpites cancellatus (Balme & Henn)												X	X		X			X	
Striatopodocarpites sp. cf. *S. phaleratus* (Balme & Henn)															X				
Thymospora cicatricosa (Balme & Henn)															X	X		X	X
Verrucosisporites pseudoreticulatus Balme & Henn						X			X	X	X	X					X		
Verrucosisporites sp. cf. *V. naumovae* Hart											X	X	X	X	X				
Verrucosisporites sp.												X							
Vesicaspora sp.											X								
Vestigisporites sp.					X						X	X			X		X	X	X
Vitreisporites signatus Leschik																			
Acritarchs and algal forms																			
Baltisphaeridium sp.					X	X													
Botryococcus sp															X				X
Brazilea sp.															X	X	X		
Cymatiosphaera sp. of Truswell 1978																		X	
Dilatosphaera sp.					X														
Elektoriskos sp.												X							
Gorgonisphaeridium sp. A. of Truswell 1978						X	X	X								X			
Gorgonisphaeridium sp.																			
Michrystridium sp. A.												X	X	X				X	X
Michrystridium sp. B.												X							X
Peltacystia venosa Balme & Segroves												X							
Quadrisporites horridus Hennelly													X						
Tasmanites punctatus Newton				X															
Tetraporina sp.													X						
Ulanisphaeridium berryense McMinn												X			X				
Veryhachium sp. cf. *V. riburgense* Brosius & Bitterli													X						
Veryhachium sp. A. of Foster 1979												X							
Veryhachium sp. B.													X			X	X	X	
Veryhachium sp. indet.				X								X							

TABLE 1 - Distribution of species of spores, pollen and acritarchs in samples examined.

Late Palaeozoic Borehole Section at Douglas River, Tasmania

Acritarchs are sparse in the lower part of the Lower Marine Sequence, except for *Tasmanites* at 321 m. In the counted sample at 313 m, spores and pollen outnumber

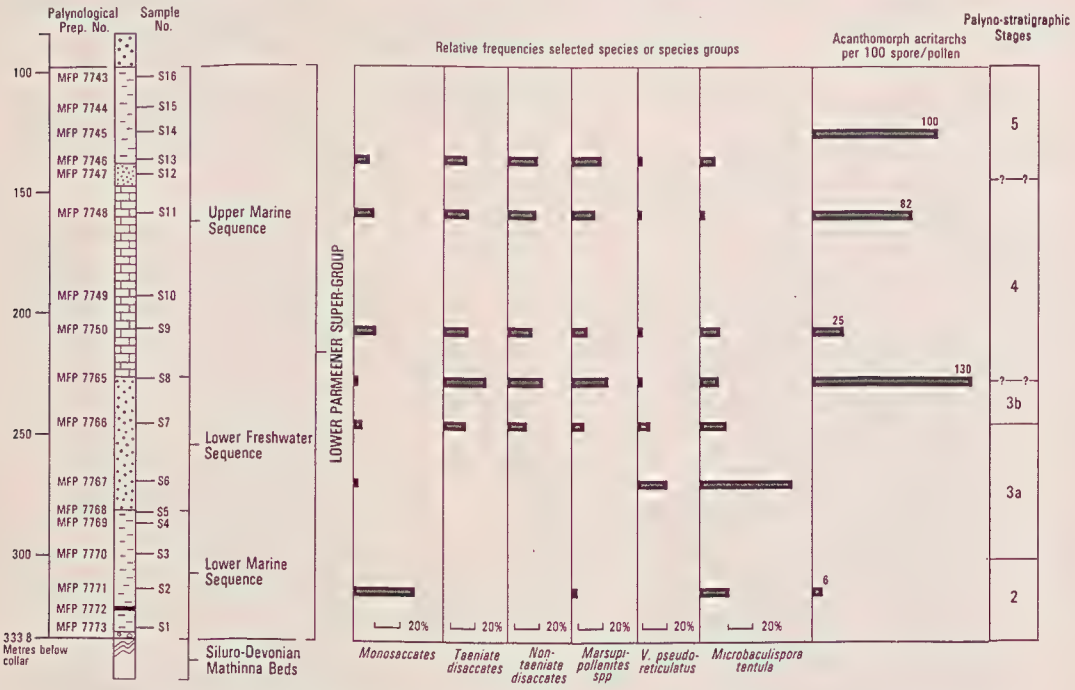

FIG. 4 - Relative frequencies of selected palynomorph species or species groups in Douglas River borehole. Frequencies are based on a count of 200 specimens: only intervals with good preservation have been counted. Second column from the right shows numbers of acanthomorph acritarchs per 100 grains of spore/pollen.

acritarchs by 10:1 (fig. 4). Prominent among the acritarch element in that sample are thin-walled, much corroded forms with long flexible processes; these are provisionally assigned here to *Baltisphaeridium* (plate 1, fig. 6,7). No such forms have been recorded previously from Australian sequences; their general morphology is more suggestive of Early Palaeozoic types, so that the possibility remains of their being reworked from the Siluro-Devonian sequences underlying the Late Palaeozoic rocks. There are no published records to date of acritarchs from the Silurian/Early Devonian in Australia, so this suggestion is impossible to test.

A single specimen referred to the Early Palaeozoic genus *Dilatosphaera* was observed at 313 m. The presence of an acritarch with distally flaring processes in unusual in the Late Palaeozoic, and again, reworking from older rocks remains possible.

Upper Stage 2 microfloral assemblages were reported previously from the lower part of the Masseys Creek Group at Beaconsfield, and from the basal part of the Quamby Mudstone at Golden Valley (Truswell 1978). At both these localities the assemblages occurred in marine sequences, were impoverished in species, and dominated by monosaccate pollen. In the Hellyer Gorge area and at Latrobe, similarly impoverished, poorly preserved assemblages occur in *Tasmanites* shale at the base of the Inglis Siltstone and Spreyton Beds respectively.

Stage 3

The appearance of the probable fern spore *Verrucosisporites pseudoreticulatus* Balme & Hennelly (this name is used for the taxon concerned rather than the later name *Pseudoreticulatispora pseudoreticulata* except in biostratigraphic terms) has been unanimously adopted by Australian palynologists as a chronostratigraphic marker. Its appearance post-dates the incoming of the first taeniate disaccate pollen in sedimentary basins in Western Australia, South Australia, Queensland and New South Wales (see Kemp *et al.* 1977; Foster 1979, 1983; Cooper 1983; Price 1983). Its first appearance defines the base of Stage 3, or the base of the *Pseudoreticulatispora pseudoreticulata* to *Phaselisporites cicatricosus* Interval Zone of Price (1983). Thus while the hazards of defining a biozone on the appearance of a single species are admitted, the consistency of appearance of this species and its ubiquitous distribution (but see Foster 1983) appear to make it a reliable marker. The resistant nature of the species has been noted by Cooper (1983).

Substage 3a

In the Douglas River borehole the deepest observed occurrence of *V. pseudoreticulatus* was at 299 m, within the Lower Marine unit. This sample, and Stage 3 samples above it in the Lower Marine Sequence yielded assemblages of poor preservation and low diversity, differing little from Stage 2 assemblages below. They contain a consistently high component of monosaccate pollen, the trilete *Microbaculispora tentula* and the monocolpate *Cycadopites cymbatus*. Also present in this upper part of the Lower Marine Sequence are acritarchs showing a basic similarity to those designated *Gorgonisphaeridium* sp. A by Truswell (1978).

Intervals sampled at 299 m, 287 m, 282 m and 269 m are referable to Substage 3a; this is the *Pseudoreticulatispora pseudoreticulata* to *Granulatisporites trisinus* Interval Subzone of Price (1983). The sample at 269 m, from the lower part of the Lower Freshwater Sequence, shows a not unexpected change in palynofacies and preservation from the intervals sampled below. In it, trilete spores are dominant, *M. tentula* and *V. pseudoreticulatus* together making up nearly 90 per cent of the assemblage (fig. 4). The species assigned tentatively to *Rattiganispora* by Truswell (1978) is also present. The assemblage is poorly diversified, with only ten species identified. The high frequency of the heavy-walled *V. pseudoreticulatus* suggests that the assemblage derives from plants growing very close to the depositional site; the near-absence of saccate pollen confirms that local, rather than regional vegetation is represented here.

Substage 3a microfloras have been identified previously in Tasmania from the Golden Valley Group near Poatina, from the Andersons Creek borehole at Beaconsfield, from the Inglis Siltstone in the Hellyer Gorge-Wynyard area, and from the Kansas Creek Beds at Fisher Tunnel (Truswell 1978). At all of these localities the biozone is developed in marine units; there is no previous record of the distinctive facies present at 269 m in the Douglas River borehole.

Substage 3b

Only one sampled level, that at 245 m, in the upper part of the Lower Freshwater Sequence, could be assigned to Substage 3b. This sample shows a marked increase in palynomorph diversity in comparison with the intervals sampled below. The basis for its attribution to Substage 3b lies in the presence of *Granulatisporites trisinus* Balme & Hennelly, the first appearance of which, in mainland successions, consistently succeeds that of *V. pseudoreticulatus*. In addition to this marker species, the Substage is distinguished by an increase in the diversity of other trilete spores; *Marsupipollenites* types assume a significant frequency, as do disaccate pollen, both taeniate and non-taeniate. This diversity, with the significantly higher frequency of winged pollen types, suggests that the pollen and spore assemblage reflects vegetation from a much wider area than is the case for the sample from 269 m.

It is notable that this is the first record for Tasmania of the Substage 3a/3b boundary occurring within a non-marine sequence, rather than below it. In the Golden Valley borehole near Poatina, the 3a/3b transition occurs within the marine sequence just below the non-marine Liffey Sandstone.

Stage 4

The base of this palynostratigraphic unit is tentatively identified as lying immediately below the interval sampled at 227 m. This base is identified on the first appearance of *Gnetaceaepollenites sinuosus* (Balme & Hennelly), with the acknowledgement that this form is not always a dependable time marker, as irregularities in its appearance in the Bowen Basin have shown (Foster 1983). The species which has come to be regarded as defining the base of Stage 4, viz. *Thymospora cicatricosa* (Balme & Hennelly), does not appear until higher in the Douglas River section, but the overall composition of assemblages at 227 m seems to warrant attribution of that interval to Stage 4. At that level, disaccate pollen, both taeniate and non-taeniate, makes up over 50 per cent of the assemblage, and *Marsupipollenites* species are abundant. This composition shows a strong similarity to Stage 4 assemblages on the Australian mainland; the gross composition of suites from the Blair Athol Coal Measures, for instance, is close to that from this Tasmanian site.

The top of Stage 4 at Douglas River is estimated to lie between horizons sampled at 159 m and 143 m, but, as is explained below, it can be only tentatively drawn. It has not been possible to assign the Stage 4 interval to Substages. The comparable assemblages from the Blair Athol Coal Measures have been referred to Upper Stage 4a (Foster 1979), on the basis of the combined presence in them of *T. cicatricosa* and *G. sinuosus*, with the latter species making the later appearance in Queensland. At Douglas River these two species appear in reverse order, so that the stage subdivisions could not be satisfactorily applied. The youngest subdivision of Stage 4 in mainland eastern Australia, Upper Stage 4b, is marked by the incoming of *Acanthotriletes villosus* Balme & Hennelly, another species which was not observed in the Douglas River samples.

Stage 5

The sampled intervals at 143 m, 137 m, 125 m, 115 m and 102 m are somewhat arbitrarily considered to be equivalent to palynological Stage 5 of the mainland sequence. This assignment rests on faunal correlation only, as palynological changes within the Upper Marine Sequence are barely perceptible. None of the forms which elsewhere characterize Stage 5, or the equivalent *Dulhuntyispora* Assemblage of Western Australia, were observed at Douglas River. No representatives were seen of the *Dulhuntyispora* complex, nor were *Didecitriletes ericianus* (Balme & Hennelly) or *Microreticulatisporites bitriangularis* Balme and Hennelly observed.

The assemblages from this upper member of the Upper Marine Sequence are characterized by relatively high frequencies of both taeniate and non-taeniate disaccate pollen, by trilete spores such as *Marsupipollenites* spp., *Granulatisporites micronodosa* Balme & Hennelly, *Granulatisporites trisinus* and *Microbaculispora tentula*, and by the monolete *Thymospora cicatricosa* and *Polypodiisporites leopardus* (Balme & Hennelly). All of these trilete and monolete species begin their ranges in much older parts of the sequence; none are confined to this interval. Among the disaccate pollen, the presence of *Striatoabieites richteri* (Klaus) is noteworthy; this distinctive species was recovered only from 143 and 125 m. In the northern hemisphere it appears to be restricted to Late Permian sequences; this is its first record from Australia, so that its range here is undocumented, but it may have potential as a stratigraphic marker.

Previous records of Late Permian assemblages from Tasmania are in accord with the impoverished assemblages from the Douglas River site. For example, among species listed by Balme (in Banks & Naqvi 1967) from the Cygnet Coal Measures at Cradoc, Mt Pelion, Mole Creek and Western Bluff, only *Acanthotriletes ericianus* gave a clear correlation with Stage 5 assemblages from the mainland. Preparations from the Jackey Shale at Western Bluff (Balme, in Jennings 1963) were recently re-examined by C.B. Foster (pers. comm., 1983), who confirmed the near absence in them of Stage 5 markers, noting that there was, however, an unusual abundance of *Bascanisporites undosus* Balme & Hennelly and *T. cicatricosa*.

The causes of the impoverishment of Late Permian palynofloras in Tasmania, in which the apparent absence of the *Dulhuntyispora* complex is noteworthy, remain speculative, but are possibly to be found in Permian climatic gradients. Continental reconstructions for

the Late Permian place Tasmania at the highest of the Australian palaeolatitudes, at approximately 70°S (Smith, Hurley & Briden 1981). The Canning and Carnarvon Basins, where Stage 5 palynofloras are most diverse, lay by contrast in 40°-50°S latitude. The poverty of the Tasmanian assemblages is paralleled by that of apparently coeval assemblages from sites in the Transantarctic Mountains of Antarctica. There, Kyle & Schopf (1982) have described suites from the Queen Maud and Upper Mt Glossopteris Formations, which are distinguished by a high frequency of taeniate disaccate pollen, by *Bascanisporites undosus* and *Gnetaceaepollenites sinuosus*, and which lack *Dulhuntyispora* and other "typical" Stage 5 indicators. The suggestion that climatic gradients may influence the distribution of the *Dulhuntyispora* group of spores on the Australian mainland has been made recently (Brakel 1982) but the stratigraphic implications of such a distribution pattern remain to be established.

Taxonomic Notes

1. Acritarchs

The acritarchs represent a probably polyphyletic group of organic-walled microfossils. Most, however, seem likely to represent the encysted phases of aquatic algae. The diversity and stratigraphic utility of the acritarchs is greatest in the Early Palaeozoic, reaching an acme perhaps in the Ordovician. On a world-wide basis, studies of Permian acritarchs have lagged behind those of the Early Palaeozoic. Such studies as do exist indicate that as a generalisation, Permian acritarch assemblages are distinguished by their low diversity and by the morphological simplicity of their constituent forms (Jacobson, Wardlaw & Saxton 1982). The causes of such taxonomic poverty in the later Palaeozoic remain obscure.

Late Palaeozoic (and Early Mesozoic) sediments are characterised in particular by "swarms" of acritarchs, in which only one or two morphologically simple types predominate. Such swarms are typical of marine basal Triassic sediments in many parts of the world (Balme & Helby 1973), but are known from Permian sediments also (Wall & Downie 1963, Balme 1970). In Australia, Evans (1962) was the first to report acritarchs in great abundance from Permian sediments in the Denison Trough of Queensland, where simple spinose forms provided a useful biostratigraphic marker horizon. The history of the usage and terminology of Evans' (1962) "P3c acritarch swarm" has recently been described by Price (1983). Spinose acritarchs suggesting brackish conditions or conditions of marine influence have been reported in lesser abundance by Foster (1974) from the Yorke Peninsula, South Australia, by Segroves (1970) from the Perth Basin, Western Australia, by Kemp (1976) from the Officer Basin, by Grebe (1970), Helby (1973) and McMinn (1982) from the Sydney Basin, by Foster (1979), Rigby & Hekel (1977) and Price (1983) from Queensland Basins, and earlier from Tasmania by Truswell (1978). In spite of this abundance of records, formal taxonomic descriptions of Permian acritarchs have been few, and the potential stratigraphic value of the group in Australian Permian sequences remains unrealised.

In the course of the present study, it became apparent that the acritarchs observed had limited stratigraphic distributions within the Douglas River sequence, or were confined to particular facies. While detailed taxonomic treatment, which requires high magnification photomicrography and statistical treatment, could not be undertaken, it was felt that illustration and brief description of common forms would serve to direct attention to the possible value of the organisms in future stratigraphic refinement.

The most abundant forms seen in the Douglas River section, viz. those referred to the genera *Michrystridium*, *Veryhachium* and *Gorgonisphaeridium*, are typical of Permian acritarch assemblages as these are known elsewhere. Another group, which includes forms referred to *Baltisphaeridium*, *Elektoriskos* and *Dilatosphaera*, are morphologically closer to Early Palaeozoic forms and have not been recorded in Australian Permian sequences before. They occur predominantly in the lower part of the sequence, which raises the possibility that they may have been reworked from Early Palaeozoic rocks.

Group ACRITARCHA Evitt, 1963

Subgroup ACANTHOMORPHITAE Downie, Evitt and Sarjeant emend Lister, 1970.

Genus *Baltisphaeridium* Eisenack emend Downie & Sarjeant, 1963

Baltisphaeridium sp.

Plate 1, figs 6,7

Remarks: Thin-walled acritarchs of near-circular outline, bearing numerous flexible, hollow, much-folded processes are referred to this category. The processes taper to an acute tip. Assignment to *Baltisphaeridium* is tentative; it assumes that the processes are closed proximally and do not communicate with the vesicle interior. This is hard to verify given the state of preservation and the intense folding of the specimens. Recorded from the middle section of the Lower Marine Sequence.
Dimensions: Vesicle diameter 38-57 μ; processes 15-25 μ long (based on 8 specimens from sample MFP 7771).

Genus *Dilatosphaera* Lister, 1970

?Dilatosphaera sp.

Plate 1, fig. 3

Remarks: This single specimen, which has a thin-walled, much-folded vesicle bearing 8 or 9 hollow, flexible processes which are distally open and flaring, is reminiscent of the chorate dinocysts found in post-Palaeozoic rocks. It has been tentatively assigned to *Dilatosphaera*, a genus which Lister (1970) erected to accommodate Early Palaeozoic acritarchs with broad, distally open processes which are proximally closed off from the vesicle cavity. The specimen figured here, from the Lower Marine Sequence, has processes which are only doubtfully closed proximally, hence the tentative generic assignment. No comparable forms have hitherto been recorded from Australian Permo-Carboniferous deposits.
Dimensions: Vesicle diameter 33 μ; processes 4-5 μ in diameter, 19-23 μ long.

Genus *Elektoriskos* Loeblich, 1970

Elektoriskos sp.

Plate 1, fig. 4

Remarks: The genus was erected (Loeblich 1970) to accommodate acritarchs with a circular vesicle outline, from which project numerous slender, flexible but solid processes. Between 50 and 60 processes are visible at the circumference. In the single specimen observed here, from the base of the Upper Marine Sequence, the wall is distinctly spongeose. The processes appear to be solid, but poor preservation makes confirmation of this difficult. Specimens of this morphology are rare in the Late Palaeozoic, and none has been recorded from Australia before.
Dimensions: Vesicle diameter 35 μ; processes 18-20 μ long, 1.0-1.5 μ in basal diameter.

Genus *Gorgonisphaeridium* Staplin, Jansonius & Pocock, 1965

Gorgonisphaeridium sp. cf. *G.* sp. A of Truswell, 1978

Plate 2, figs 8,9

cf. 1978 *Gorgonisphaeridium* sp. A, Truswell, p.27, Pl.3, fig.1-6.

Remarks: To this category are assigned acritarchs bearing numerous, solid processes which are slightly tapering and bluntly truncated apically. There may be some slight recurving at the distal extremity of the processes. At the process base there are poorly defined,

radially arranged ridges on the vesicle wall. Excystment is apparently by simple splitting of the vesicle wall.

The morphology shows a basic similarity to specimens described by Truswell (1978) as *Gorgonisphaeridium* sp. A, except for a denser cover of processes and a less distinctly linear arrangement of these. The specimens figured here may have some stratigraphic value as they were restricted to the upper part of the Lower Marine Sequence. *Gorgonisphaeridium* sp. A was recorded (Truswell 1978) from a comparable stratigraphic interval, in the Quamby Mudstone and its correlatives, in association with a Substage 3a microflora.
Dimensions: Test diameter 34-61 μ; processes 3-4 μ high; 1.5-2.0 μ in basal diameter (based on 5 specimens from sample MFP 7770).

Gorgonisphaeridium sp.

Plate 1, fig. 5

Remarks: In the possession of a thick wall, a median split, and densely spaced solid processes, this form bears some similarity to *Gorgonisphaeridium cumulatum* Playford, from the Emsian of Ontario (Playford 1977, pl.8, figs 12-20) although processes are shorter in the Tasmanian form. It differs from the superficially similar *Michrystridium evansii* Price (Price 1983, p.177, pl.16, figs 1-6,8,13) in having apparently solid processes (hence assignment to *Gorgonisphaeridium*) and in having a thicker wall.
Dimensions: Vesicle diameter 32, 37 μ (2 specimens from sample MFP 7747, Upper Marine Sequence).

Genus *Ulanisphaeridium* McMinn, 1982

Ulanisphaeridium berryense McMinn, 1982

Plate 1, fig. 1

1982 *Ulanisphaeridium berryense* McMinn, p.82, pl.1, figs 7-9; pl.2, figs 4,6.

Remarks: In the presence of a circular pylome, 1.8-2.0 μ in diameter, and of a two-layered wall bearing a surface ornament of essentially club-shaped processes which are frequently united at their tips, there can be little doubt that the Tasmanian specimens are conspecific with *U. berryense*, described by McMinn (1982) from the northern Sydney Basin. The processes of the periphragm are very irregular; some are united to form an irregular mesh-like structure, while others remain discrete. The endophragm is homogeneous, 1.5-2.0 μ thick. McMinn placed specimens assigned by Grebe (1970, pl.6, figs 7,10), Helby (1973, pl.3, fig.10) and Foster (1979, pl.40, figs 2,3) to *Michrystridium* within *U. berryense*. In the form of its surface ornament, *U. berryense* shows some similarity to *Mehlisphaeridium regulare* Anderson, 1977 from the Ecca Series of South Africa (Anderson 1977) but the presence of a pylome has not been established for that species.
Dimensions: Vesicle diameter 27-29 μ (3 specimens from sample MFP 7765, uppermost part of Lower Freshwater Sequence).

Genus *Michrystridium* Deflandre, 1937

Michrystridium sp. A

Plate 2, figs 1-3, 5

Remarks: Grouped within this category are spinose acritarchs with an originally spherical vesicle, bearing hollow, broad-based spines which are open to the vesicle interior. The processes taper sharply to an acute tip; rarely are they bifurcating. The vesicle usually shows compressional folding. Dehiscence is by median splitting.

For acanthomorph acritarchs such as these, which show a minimum of morphological features on which their characterisation might rest, statistical studies are necessary to identify morphological discontinuities between species. Such are beyond the scope of the

present paper. Such studies should also form the basis of meaningful comparisons with previously described taxa, but are not available in the present state of Permian acritarch research. *Michrystridium* sp. A bears some resemblance to *M. breve* Jansonius, from the Early Triassic of western Canada (Jansonius 1962), which was subsequently recorded by Sarjeant (1970) from the Salt Range, Pakistan. The Tasmanian specimens are, however, considerably larger. They are common in the Upper Marine Sequence, and occur in "swarm" proportions in sample MFP 7765, at the very top of the Lower Freshwater Sequence.
Dimensions: Vesicle diameter 21-27 μ; spines 3-5 μ long, 1.5-1.8 μ in basal diameter (based on 8 specimens from sample MFP 7765).

Michrystridium sp. B

Plate 2, fig. 4

Remarks: This category includes forms with an originally spherical vesicle and a dense cover of straight, spinose processes which are usually simple but which may bifurcate at their tips. The more dense concentration of spines, and their narrower basal diameters distinguish this form from *Michrystridium* sp. A. The straight, densely distributed processes distinguish the form from *Michrystridium* sp. A of Foster (1979) from the Baralaba Coal Measures of Queensland. *Michrystridium* sp. A was recorded here only from sample MFP 7765, at the top of the Lower Freshwater Sequence.
Dimensions: Vesicle diameter 21-25 μ, spines 6-7 μ long, 1.0-2.0 μ in basal diameter (3 specimens from sample MFP 7765).

Subgroup POLYGONOMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus *Veryhachium* Deunff ex Downie, 1959

Veryhachium sp. cf. *V. ?riburgense* Brosius & Bitterli, 1961

Plate 1, figs 8-10

Remarks: Herein are grouped forms with a basically triangular or quadrangular test which bears 5 to 8 hollow processes which are very broad at the base, continuous with the vesicle interior, and which taper to an acute tip. The vesicle exterior is smooth. No dehiscence structure was observed.

Morphologically this is a highly variable, although distinctive, group. It seems best in this preliminary study to regard all variants as belonging to a single species, which is comparable to the *Veryhachium ?riburgense* plexus of Brosius & Bitterli (1961) but the Tasmanian specimens represent a much larger form. Sarjeant (1970) recognised the *V. ?riburgense* complex in the Chhidru Formation of the Salt Range, but the specimens he reported there are about half the size of those from Tasmania. None of the species reported from the German Zechstein by Schaarschmidt (1963) closely resembles the Tasmanian species; the highly variable *Veryhachium variabilis* Schaarschmidt (1963, pl.18, fig.4-6) is closest, but has processes which are more constricted at the base. In the Douglas River sequence this form occurs only in the Upper Marine Sequence, where it is most abundant in sample 7750.
Dimensions: Vesicle diameter 28-37 μ; processes 9-23 μ long, 4-10 μ in basal diameter (based on 7 specimens from sample MFP 7750).

Veryhachium sp. A of Foster, 1979

Plate 1, fig. 2

1979 *Veryhachium* sp. A, Foster, p.111, pl.40, fig. 5.

Remarks: This species includes specimens of *Veryhachium* with relatively short, broad-based processes, which show the suggestion of a bipolar distribution. The processes are much shorter in relation to vesicle diameter than they are in the cf. *V. ?riburgense* type. The vesicle wall is faintly granular. The form conforms closely to that which Foster (1979)

described from the Baralaba Coal Measures; it is probably identical to the *Veryhachium* types reported by Grebe (1970, pl.6, fig.11) and Helby (1973, pl.3, fig.12) from the basal *Protohaploxypinus reticulatus* Zone, above the youngest coal measures in the Sydney Basin. In the present study it was observed only in sample 7765, at the top of the Lower Freshwater Sequence.
Dimensions: Vesicle diameter 20, 22 μ; processes 4-6 μ long, 1.5-3.0 μ in basal diameter (based on 2 specimens from sample MFP 7765).

Veryhachium sp. B

Plate 2, fig. 6

Remarks: Within this category are placed small, thin-walled *Veryhachium* specimens with convex sides, suggesting an originally globular form of the vesicle. The processes are hollow, long and flexible, and communicate with the vesicle interior. One "apical" process is frequently bifurcating. An arcuate split was observed on some specimens, and encompasses one process. Whether or not this represents a definite excystment structure is uncertain. The form was observed only in the Upper Marine Sequence.
Dimensions: Vesicle diameter 13-17 μ; processes 9-12 μ long (based on 5 specimens from sample MFP 7750).

Subgroup SCHIZOMORPHITAE Segroves, 1967

Genus *Brazilea* Tiwari & Navale, 1967

Brazilea sp.

Plate 2, fig. 10

Remarks: Forms grouped here are spherical, and occur usually in aggregates, Individuals are frequently ruptured, with rupturing occurring along a single dehiscence line. The surface of the test ranges from finely granular, in which instance they resemble *Brazilea helbyi* Foster (Foster 1979, p.112, pl.40, fig.20,21), to forms with a dense fibrous covering. Whether this fibrous mat represents the original surface, the remains of material originally enveloping the cellular mass, or results from the breakdown of the cell walls, is uncertain. The form occurs in swarm proportions at certain levels in the Upper Marine Sequence.
Dimensions: Vesicle diameter 15-41 μ (based on 20 specimens from sample MFP 7747).

2. Spores and pollen

Those spores and pollen described briefly here are those for which the present record represents a first report, either in Tasmania or in Australia, or represents a modification of stratigraphic ranges as previously understood.

Trilete spores

Genus *Camptotriletes* Naumova ex Potonié & Kremp, 1954

Camptotriletes biornatus Balme & Hennelly, 1956

Plate 2, fig. 11

1956 *Camptotriletes biornatus* Balme & Hennelly, p.252, pl.5, fig.55-56.

Remarks: Specimens assigned here to *C. biornatus* have greatly reduced ornament on the proximal face, well developed sinuous labra enclosing the laesurae, and a distal ornament of rugulae constructed apparently of joined verrucae. Occasional isolated verrucae are also present on the distal face.

Camptotriletes biornatus was, at the time of the erection of the species (Balme & Hennelly 1956) recorded only from the Greta Coal Measures in the Sydney Basin. This record

from Tasmania, from a comparable stratigraphic interval at the top of the Lower Freshwater Sequence, appears to be the first report of the species published since then.
Dimensions: Equatorial diameter 68, 70 μ (2 specimens from sample MFP 7765).

Genus *Didecitriletes* Venkatachala & Kar, 1965

Didecitriletes sp. cf. *D. uncinatus* (Balme & Hennelly) Venkatachala & Kar, 1965

Plate 3, fig. 4

cf. 1956 *Acanthotriletes uncinatus* Balme & Hennelly, p.249, pl.3, fig.35-36.
cf. 1965 *Didecitriletes uncinatus* (Balme & Hennelly) Venkatachala & Kar, p.339.

Remarks: The single specimen reported here has a smooth, sharply delineated proximal face, with laesurae surrounded by labra about 2.0 μ high. The spinose elements of the distal face taper evenly from bases 0.7-0.8 μ in diameter to reach a maximum height of 3.5 μ. They are clearly longest in the equatorial, interradial regions, and shortest in the distally subequatorial radial areas. This distribution of ornament is reminiscent of that in *Diatomozonotriletes*, although reduction of ornament distally is more extreme in that genus.

The sharply triangular outline, labrate laesurae and spine shape are close to features shown by *D. uncinatus*. That species has only been reported previously from stratigraphic intervals equivalent to Stage 5; this Tasmanian record, from the top of the Lower Freshwater Sequence, is from basal Stage 4. Price (1983) however, noted that acanthine trilete forms occur in pre-Stage 5 sediments in some Queensland basins. These specimens have a sharply delineated proximal face, which Price (pers. comm., 1983) suggests represents a difference from *D. uncinatus*, which bears reduced spines proximally. The Tasmanian specimen may thus be conspecific with those reported, but as yet undescribed, from Queensland Stage 3 and 4 sequences.
Dimensions: Equatorial diameter 36 μ.

Didecitriletes sp. cf. *D. eoericiana* (Anderson) comb. nov.

Plate 3, fig. 5

cf. *Microbaculispora eoericiana* Anderson, 1977, p.150, pl.55, figs 7-20.

Remarks: Only two torn specimens of this distinctive type were observed. The surface ornament consists of two separate elements; there are spines, on average 4.5 μ long, tapering smoothly to an acute tip, which are interspersed with baculae 1.0 μ high, 0.3-0.4 μ in basal diameter, and blunt-tipped. From the fragmented specimens available, it is apparent that the proximal face is smooth. Although the preservational state of the specimens precludes precise identification, the available morphological data suggest that the species is very close to *Microbaculispora eoericiana*, which Anderson (1977) described from the Lower Ecca in South Africa, from an interval not far above the Dwyka Tillite. The Tasmanian specimens were recovered from the top of the Lower Freshwater Sequence.

Genus *Granulatisporites* Ibrahim emend Potonié & Kremp, 1954

Granulatisporites sp. cf. *G. micronodosa* Balme & Hennelly, 1956

Plate 3, fig. 1

cf. *Granulatisporites micronodosus* Balme & Hennelly, 1956, p.245, pl.1, figs 9,10.

Remarks: Specimens included here are rounded triangular, deeply convex-sided in equatorial view, with a distal ornament consisting of steep or parallel-sided processes, most of which can be classified as baculae. In the figured specimen, distal processes are 1.0-1.2 μ high, and 0.3-0.5 μ in basal diameter; they are spaced 1.0-1.5 μ apart, and are not confluent at their bases. In the latter feature they differ from superficially similar forms which fall within the range of *Verrucosisporites pseudoreticulatus*, representing a variant of that species with steep-sided processes.

The forms compared here to *G. micronodosa* are distinguished by their baculate distal processes; they differ from forms compared to *G. micronodosa* by Truswell (1978, p.23, pl.1, figs 15,16) in this feature and in being convex-sided. They were recorded throughout the Upper Marine Sequence.
Dimensions: Equatorial diameter 43-55 μ (based on 5 specimens from sample MFP 7765).

Monolete spores

Genus *Polypodiisporites* Potonié emend Khan & Martin, 1971

Polypodiisporites leopardus (Balme & Hennelly) Foster, 1975

Plate 2, fig. 7

For synonymy see Foster 1979, p.61.

Remarks: The presence of this species is noted here as there appears to be some uncertainty about its stratigraphic range elsewhere. In the Douglas River borehole it occurs throughout the Upper Marine Sequence in low frequencies. Previously published accounts suggest that it may be confined to the Early Permian. It was initially described from the Greta Coal Measures (Balme & Hennelly 1956) and was at that time recorded also from the Mersey Coal Measures at Tarleton and Illamatha. Recent studies in Queensland Basins have tended to reinforce the impression that the species may be restricted in its range; Foster (1979), for instance, reported the species as common in the Blair Athol Coal Measures (Stage 4) and suggested that rare specimens in the younger Baralaba Coal Measures might be reworked; Rigby & Hekel (1977) noted only a single specimen in the Black Alley Shale. The results of the present study indicate that, in Tasmania at least, the form has a range from probably Stage 3b through Stage 5.
Dimensions: Grain length 33-41 μ; width 28-33 μ (based on 5 specimens from sample MFP 7748).

Genus *Thymospora* Wilson & Venkatachala emend Alpern & Doubinger, 1973

Thymospora cicatricosa (Balme & Hennelly) Hart, 1965

Plate 3, figs 2, 3

For synonymy see Foster 1979, p.62.

Remarks: The figured specimen, which distally carries rugulate elements bearing recurved, acute spines at intervals, closely resembles the trilete form of this normally monolete species which was figured by Foster (1979, pl.19, fig.6). The distal ornament is identical to that of monolete specimens observed in the same sample, MFP 7748, from the Upper Marine Sequence. The proximal face is smooth in both morphotypes.

The occurrence and possible stratigraphic significance of these trilete variants has been discussed by Price (1983), who assigned the trilete forms to *Apiculatisporis cornutus* Balme & Hennelly; these forms bear the cicatricose, cristate, biform sculptural elements of *T. cicatricosa*, however, and are probably best retained within that species. According to Price, they appear late in Stage 3 just before the level where the monolete forms appear in Queensland sequences. The monolete forms define the lower boundary of Stage 4 (Price, in Kemp *et al.* 1977). In the Douglas River sequence both trilete and monolete forms appear first in sample MFP 7748, near the top of the basal member of the Upper Marine Sequence. The trilete types were present in this sample only; younger occurences, in the upper part of the Upper Marine Sequence, were of monolete types only.

In the course of the present study, slides containing the type specimen of *T. cicatricosa*, from the Greta Seam, Hebburn No.2 Colliery, were examined. Both trilete and monolete morphotypes were observed to be present.
Dimensions: Grain length 34-39 μ, width 22-27 μ (5 specimens); diameter of trilete forms 34, 35 μ (2 specimens): based on specimens from sample MFP 7748.

Monosaccate pollen

Genus *Bascanisporites* Balme & Hennelly, 1956

Bascanisporites sp. cf. *B. undosus* Balme & Hennelly

Plate 3, fig. 8

cf. *Bascanisporites undosus* Balme & Hennelly, 1956, p.256, pl.10, figs 81-83.

Remarks: Two specimens from the lower member of the Upper Marine Sequence are placed in comparison only with *B. undosus*, as no corpus could be discerned in them. In other features, such as the lobate outline of the equatorial sacci, and the presence of a small trilete tetrad scar, the forms are close to *B. undosus*. Specimens from samples higher in the sequence do show an inner body but only indistinctly.
Dimensions: Equatorial diameter 49, 55 μ (2 specimens from sample MFP 7748).

Genus *Crucisaccites* Lele & Maithy, 1964

?Crucisaccites sp.

Plate 3, figs 6, 7

Remarks: A single, well-preserved specimen found in sample MFP 7748, in the lower member of the Upper Marine Sequence, is possibly referable to *Crucisaccites*. The grain is monosaccate, with the saccus attachment such that an elongate, parallel-sided saccus-free area is present on the proximal face. On the distal face a more vaguely defined area is saccus-free; the saccus roots are arcuate on that face, leaving a near-oval area at the distal pole without saccus development. The infra-reticulum of the saccus has a strong radial component. A monolete tetrad scar is conspicuous on the proximal face.

The form does not appear to have been recorded from Australian sediments before. Assignment to *Crucisaccites* is tentative only as the saccus-free areas on the two sides of the body are not at right angles to each other (see Lele & Maithy 1964, p.307).
Dimensions: Overall breadth 63 μ, corpus breadth 46 μ; overall length 36 μ, corpus length 31 μ; saccus offlap 6 μ.

Genus *Striatoabieites* Zoricheva & Sedova emend Hart, 1964

Striatoabieites richteri (Klaus) Hart, 1965

Plate 3, fig. 9

Synonymy
1955 *Lueckisporites richteri* Klaus, 1.33, fig.1.
1963 *Strotersporites richteri* (Klaus) Wilson, 1962, in Klaus, p.316, pl.15, figs 76,77.
1964 *Striatoabieitites richteri* (Klaus, 1955) Hart, p.1186, text-fig.41.
1965 *Striatoabieitites richteri* (Klaus, 1955) Hart, p.41, text-fig.91.
1979 *Striatoabieitites richteri* (Klaus) Hart, in Balme, p.32, pl.3, figs 19-20.

Remarks: Specimens examined in the present study, from the Upper Marine Sequence, are characterised by 18-20 fine proximal taeniae (which frequently show subsidiary clefts), by a clearly discernible, geniculate tetrad scar, and by distally pendant, hemispherical sacci with a fine infra-reticulum. They are morphologically very close to Klaus' (1955) type material from the German Zechstein, and to specimens identified with *S. richteri* by Balme (1979) from Late Permian and Early Triassic strata at Kap Stosch, Greenland. The northern hemisphere records indicate that the form does not appear before the Late Permian. The Tasmanian record is the first for Australia.
Dimensions: Overall breadth 72, 84 μ; corpus breadth 43, 45 μ; saccus breadth 22-29 μ; corpus length 29, 34 μ; saccus length 29-33 μ (based on 2 specimens from sample MFP 7748, Upper Marine Sequence).

SUMMARY

Lithostratigraphic details of the Douglas River borehole are given. The Late Palaeozoic sequence is surprisingly complete for northeastern Tasmania. The occurrence of *Tasmanites* shale and associated rocks may indicate a narrow, east-west breaching of the land barrier which occupied most of northeastern Tasmania throughout the Tamarian.

Marine macro-invertebrate and palynological distributions are documented. The marine faunas indicate that the sequence ranges in age from Early Tamarian (Late Carboniferous) to Late Lymingtonian (Late Permian). The microfloras are assigned to Stages 2-5. Some acritarchs which occur low in the sequence may have been derived from earlier Palaeozoic rocks; others, which occur in swarm proportions higher up, are coeval with sedimentation. Tasmanian Late Permian palynofloras lack diversity and resemble those from the Transantarctic Mountains, Antarctica, rather than those from elsewhere in eastern Australia. The German Late Permian Zechstein species *Striatoabieites richteri* (Klaus) is recorded from Australia for the first time.

ACKNOWLEDGEMENTS

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PLATE 1 (on page 158)

All magnifications × 900. Co-ordinates are those of the Leitz Orthplan microscope 895191 in the Bureau of Mineral Resources, Canberra.

Fig. 1 *Ulanisphaeridium berryense* McMinn, 1982. CPC 24623. Slide MFP 7765/4: 95.5, 38.9

Fig. 2 *Veryhachium* sp. A of Foster, 1979. CPC 24624. Slide MFP 7765.

Fig. 3 *?Dilatosphaera* sp. CPC 24625. Slide MFP 7771/1:96.0, 33.5

Fig. 4 *Elektoriskos* sp. CPC 24626. Slide MFP 7765/3: 101.2, 47.2.

Fig. 5 *Gorgonisphaeridium* sp. CPC 24627. Slide MFP 7747/2:94.2, 43.5.

Figs 6, 7 *Baltisphaeridium* sp. 6: CPC 24628. Slide MFP 7771/1:92.2, 33.0.
7: CPC 24629. Slide MFP 7771/1:206.4, 31.5.

Figs 8-10 *Veryhachium* sp. cf. *V. ?riburgense* Brosius & Bitterli.
8: CPC 24630. Slide 7750/3:97.0, 38.1.
9: CPC 24631. Slide 7750/3:96.4, 33.5.
10: CPC 24632. Slide MFP 7750/3:95.1, 38.8.

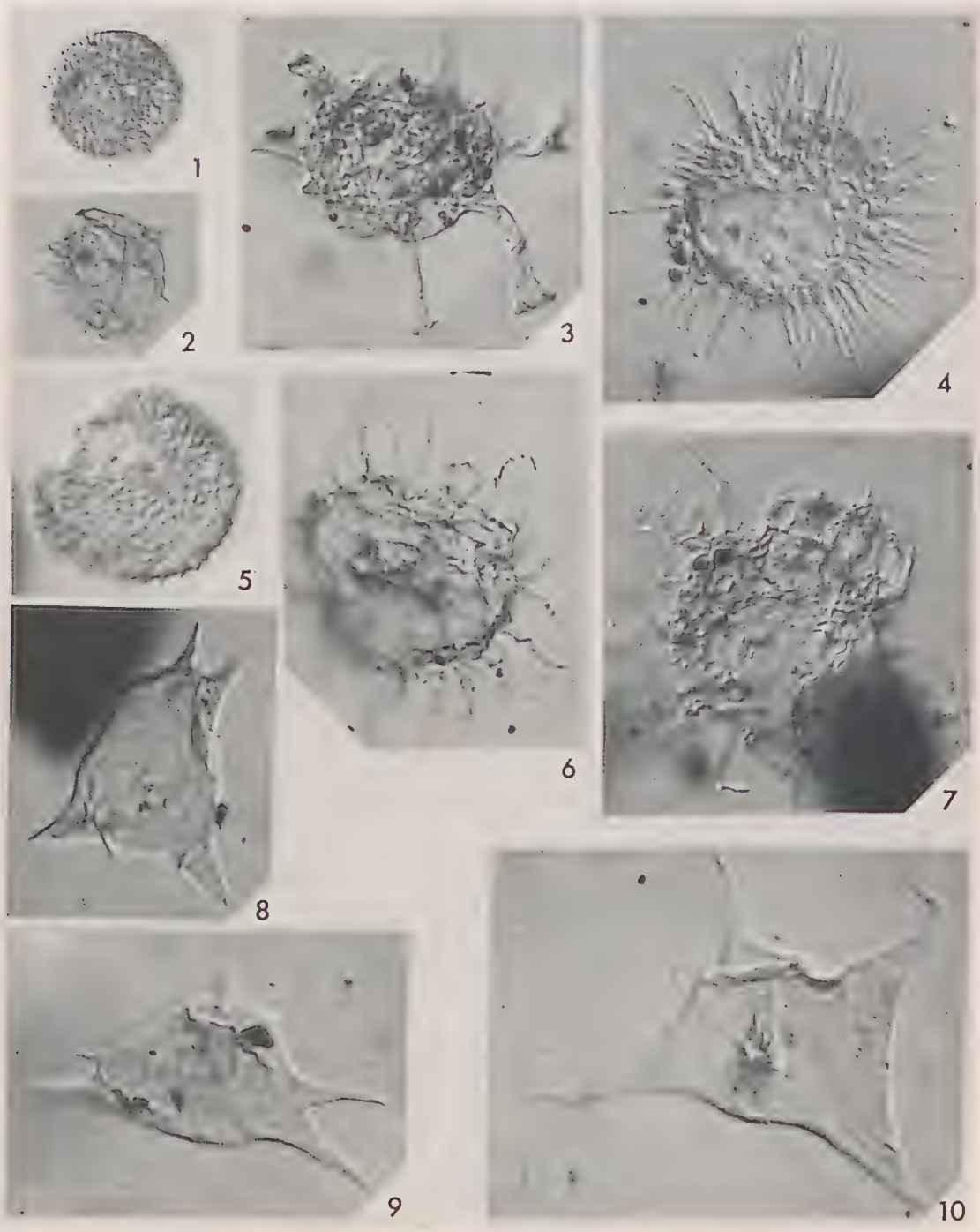

PLATE 1

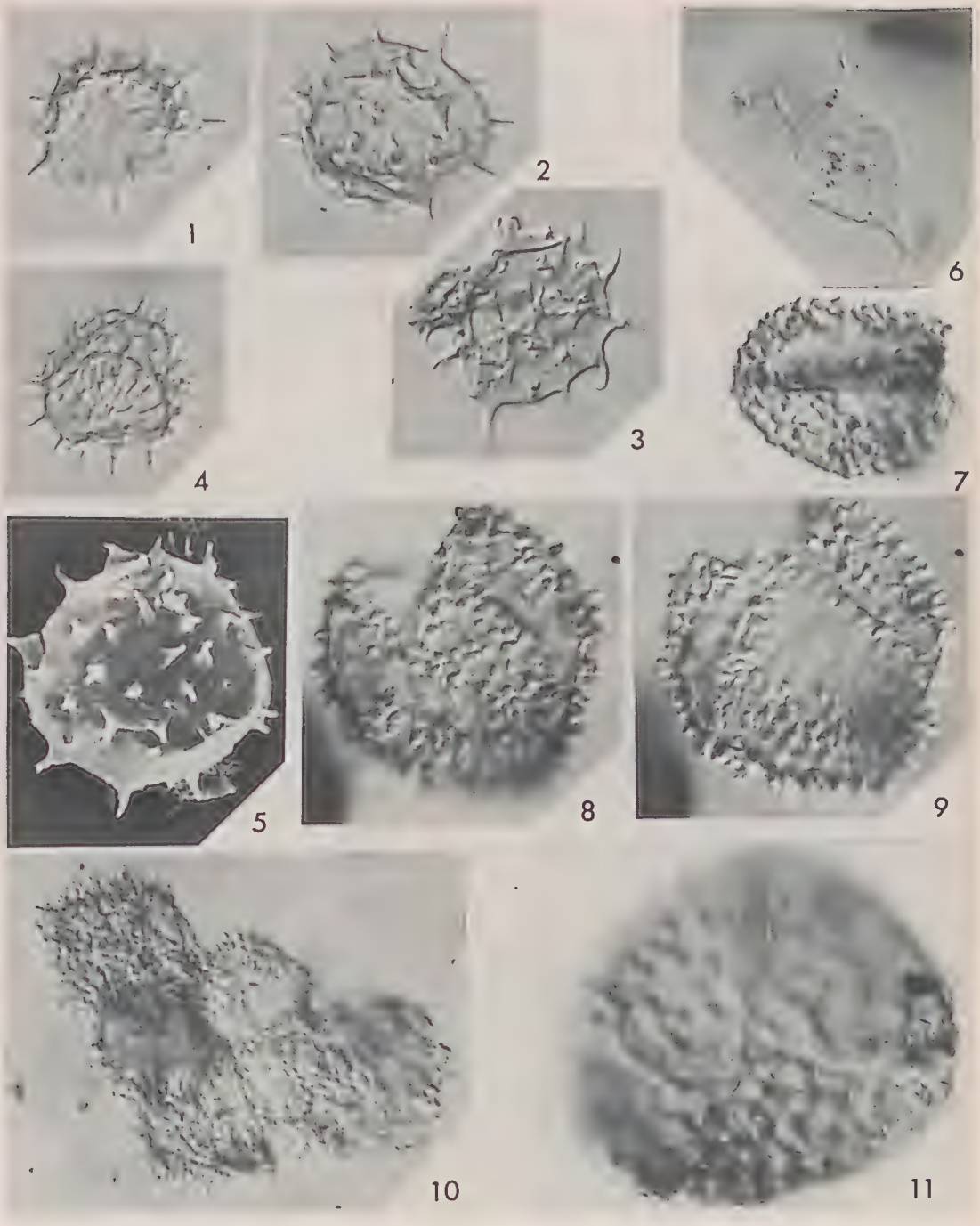

PLATE 2

PLATE 2 (on page 159)

All magnifications × 900 unless stated otherwise.

Figs 1-3, 5 *Michrystridium* sp. A. 1: CPC 24633. Slide MFP 7765/4:99.7, 30.5.
2: CPC 24634. Slide MFP 7765/4:110.0, 29.9.
3: CPC 24635. Slide MFP 7765/4:105.5, 30.2
5: Scanning electron micrograph, × 1080. CPC 24636. MFP 7765.

Fig. 4 *Michrystridium* sp. B. CPC 24637. Slide MFP 7765/3:99.2, 43.0.

Fig. 6 *Veryhachium* sp. B. CPC 24638. Slide MFP 7750/3:98.3, 37.1.

Fig. 7 *Polypodiisporites leopardus* (Balme & Hennelly) Foster, 1975.
CPC 24639. Slide MFP 7748/3:110.2, 26.7.

Figs 8, 9 *Gorgonisphaeridium* sp. cf. *G.* sp. A of Truswell, 1978.
CPC 24640. Slide MFP 7770/4:105.2, 31.6. High and median foci.

Fig. 10 *Brazilea* sp. CPC 24641. Slide MFP 7747/2:101.3, 41.5.

Fig. 11 *Camptotriletes biornatus* Balme & Hennelly, 1956. CPC 24642.
Slide 7765/4:107.7, 44.1. Distal aspect.

PLATE 3 (opposite)

All magnifications × 900.

Fig. 1 *Granulatisporites* sp. cf. *G. micronodosa* Balme & Hennelly, 1956.
CPC 24643. Slide MFP 7765/3:103.8, 36.5 Equatorial aspect.

Fig. 2, 3 *Thymospora cicatricosa* (Balme & Hennelly) Hart, 1965. CPC 24644.
Slide MFP 7748/2:93.5, 36.6. Proximal and distal foci on trilete form.

Fig. 4 *Didecitrilites* sp. cf. *D. uncinatus* (Balme & Hennelly) Venkatachala & Kar, 1965. CPC 24645. Slide MFP 7765/2:101.4, 37.0

Fig. 5 *Didecitrilites* sp. cf. *D. eoericiana* (Anderson) comb. nov. CPC 24646.
Slide MFP 7765/4:102.5, 45.2. Torn specimen.

Fig. 6, 7 *?Crucisaccites* sp. CPC 24647. Slide MFP 7748/4:104.7, 38.5. Proximal and distal foci.

Fig. 8 *Bascanisporites* sp. cf. *B. undosus* Balme & Hennelly, 1956. CPC 24647.
Slide MFP 7748/2:96.0, 41.4.

Fig. 9 *Striatoabieites richteri* (Klaus) Hart, 1965. CPC 24648.
Slide MFP 7748/3:95.5, 28.5.

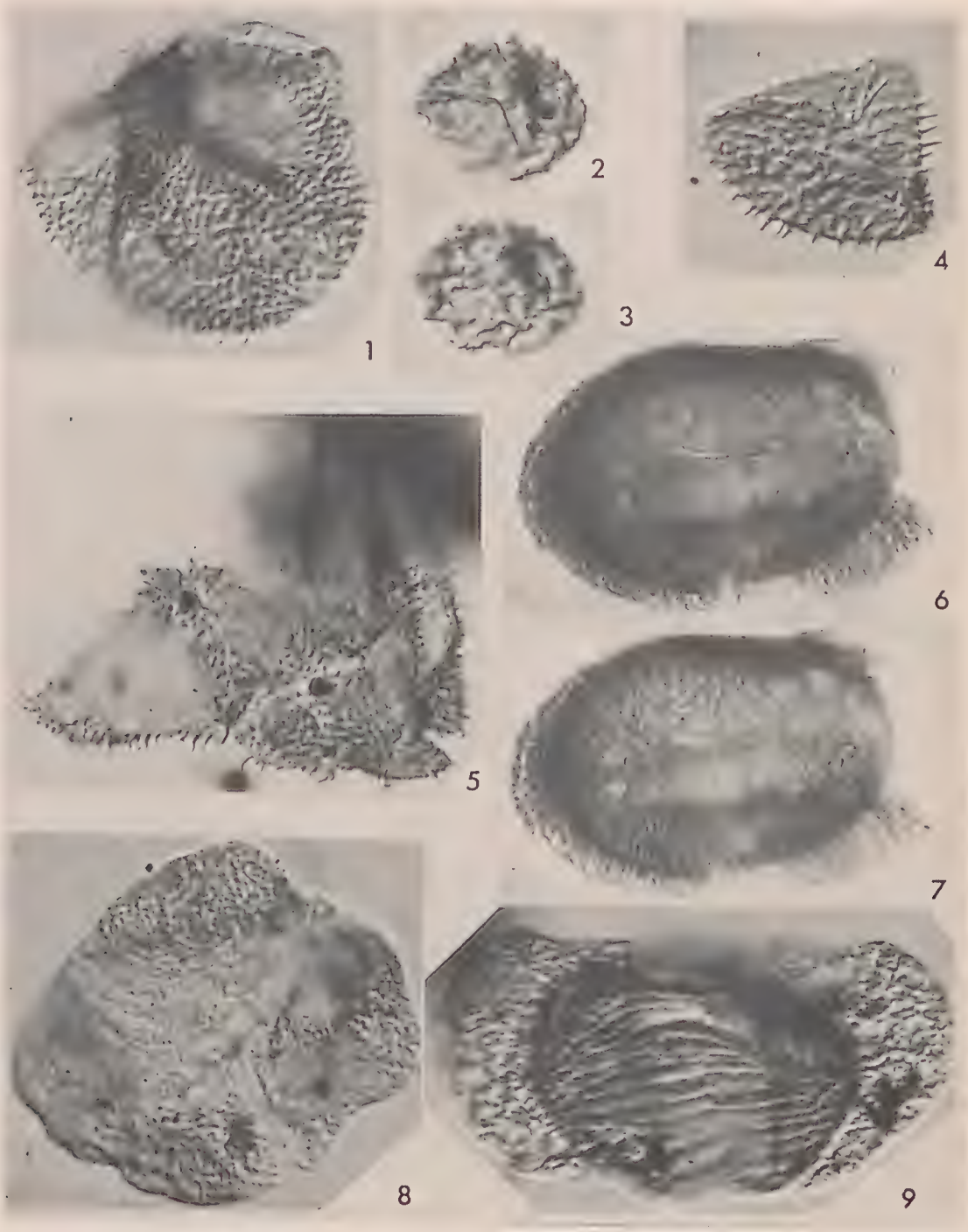

PLATE 3

Papers and Proceedings of the Royal Society of Tasmania, Volume 118, 1984

(ms. received 1.II.1983)

THE UPSTREAM MOVEMENTS OF FISH IN THE PLENTY RIVER, TASMANIA

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Inland Fisheries Commission, Hobart, Tasmania

(with one table and six text-figures)

ABSTRACT

SLOANE, R.D., 1984 (31 viii): The upstream movements of fish in the Plenty River, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 118:163 - 171. ISSN 0080-4703. Inland Fisheries Commission, Hobart, Tasmania, Australia.

A trap was installed in the Plenty River, southern Tasmania, in order to investigate upstream fish movements. The trap was monitored from May 1978 to September 1979. The catch included the lampreys *Mordacia mordax* and *Geotria australis*, the galaxiids *Galaxias maculatus*, *G. truttaceus* and *G. brevipinnis*, the sandy *Pseudaphritis urvillii*, the short-finned eel *Anguilla australis*, and a small number of blackfish *Gadopsis marmoratus*. The significance and timing of the movements of each species are discussed and related to existing knowledge.

INTRODUCTION

During the autumn of 1978 a fish trap was installed at a weir on the Plenty River, 2 km upstream from its confluence with the Derwent River in southern Tasmania (fig. 1). The upper limit of tidal influence in the Derwent River occurs 7 km below its confluence with the Plenty River.

The trapping programme was initiated in order to monitor the upstream migration of juvenile freshwater eels, *Anguilla australis* Richardson, as part of a separate study. However, during the period of trapping, a number of other species were captured. These were lampreys *Mordacia mordax* (Richardson) and *Geotria australis* Gray, the galaxiids *Galaxias maculatus* (Jenyns), *Galaxias truttaceus* (Valenciennes) and *Galaxias brevipinnis* Günther, the sandy *Pseudaphritis urvillii* (Cuvier and Valenciennes) and the blackfish *Gadopsis marmoratus* Richardson.

Little attention has been devoted to the upstream movements of these species in Australia. The spawning migrations of lampreys are well known phenomena in Australia (Potter *et al.*, 1968) but no detailed studies of these migrations have been published. Of the three galaxiids recorded in this study, the migrations of the 'whitebait' stage of *Galaxias maculatus* are the best documented. McDowall (1968) and Benzie (1968) studied this species in New Zealand, while Scott (1938) made observations on *G. maculatus* entering a Tasmanian stream. Scott (1936, 1941) also recorded migrations of juvenile *Galaxias truttaceus*. The upstream migrations of *Anguilla australis* elvers is at present being monitored in Tasmania (Sloane 1978, 1981) and in New Zealand this species has been studied in detail, most recently by Jellyman (1977). Beumer & Harrington (1982) recorded movement of both *A. australis* and *Gadopsis marmoratus* through a fish-ladder on the Lerderderg River, Victoria. There is no published information relating to upstream movement of *Pseudaphritis urvillii*.

METHODS

The upstream fish trap (figs 2 and 3) was installed at a weir which was formerly the site of a salmonid trap operated by the Tasmanian Inland Fisheries Commission. The trap was designed to capture fish migrating upstream through a diversion channel bypassing the weir. The weir forms a barrier to upstream fish migrations. Water passing through the

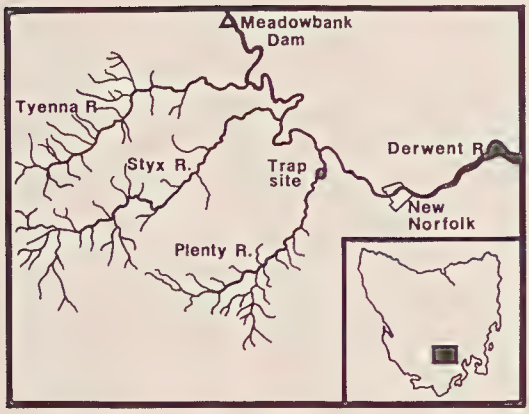

FIG. 1 - Location map showing the lower Derwent catchment and the Plenty River trap site.

diversion channel re-enters the river at the foot of the weir and provides a route for fish to pass upstream around the side of the weir.

The catching box was usually emptied each morning throughout the sampling period but on some occasions several days elapsed between the trap being cleared. On each visit, the catch was identified and counted then liberated above the weir. Sub-samples of juvenile galaxiids were preserved in 10% formalin for subsequent confirmation of identification.

Water temperatures were recorded daily at 0800 h at the Salmon Ponds trout hatchery 1 km upstream from the trap. River flow data were obtained from a gauging weir operated by the Tasmanian Rivers and Water Supply Commission on a nearby stream, the Tyenna River, at Newbury. These data were found to correspond closely to qualitative water-level observations recorded on visits to the Plenty River trap.

RESULTS

The trapping programme commenced on 1 May 1978 and continued until the trap was damaged by a sudden flood in early September 1979. The loss of the trap and the deteriorating condition of the weir made further trapping impracticable. The vast majority of fish were

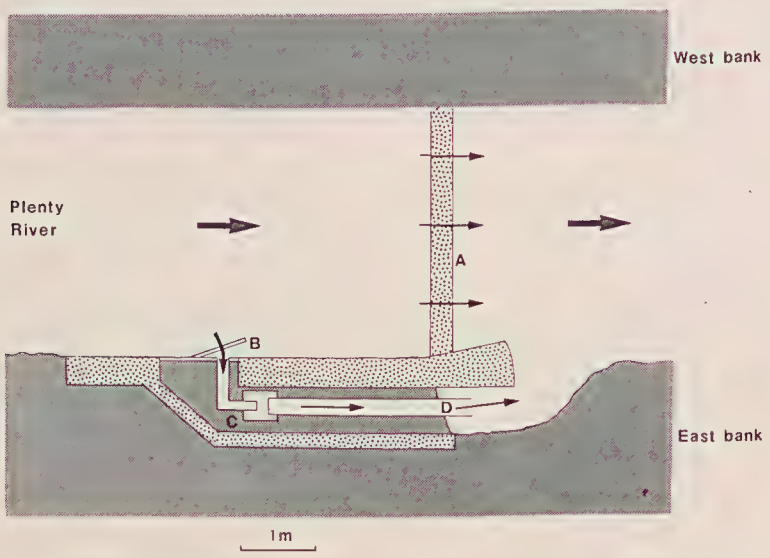

FIG. 2 - Details of the Plenty River weir and fish trap. Plan view of weir showing position of fish trap. A - weir face; B - trash screen; C - bypass channel; D - rampway entrance.

taken between mid-September 1978 and the end of January 1979. The daily catch records for this period are illustrated in fig. 4. Isolated catch records during the remainder of the 17 month sampling period are given in table 1. On occasions when the trap was visited after more than one day had elapsed, it was assumed that an equal proportion of the total catch entered the trap on each day.

Period of Migrations

The migration of 'Velasia' stage *Geotria australis* began at the Plenty River in mid-September. The onset of migration was heralded by the appearance of large flocks of cormorants seen gorging themselves on these animals in the lower reaches of the Derwent River. The migration reached its peak in October and continued until the end of November. *Mordacia mordax* first appeared in significant numbers at the Plenty River weir early in November. The numbers migrating reached the highest level at the end of November; small numbers were then caught through until early January (fig. 4). Lampreys of both species were only seen entering the trap at night. By torch light, they could also be seen climbing the rock face on the opposite side of the weir. During the day lampreys were found beneath the loose stones below the trap.

The run of *Anguilla australis* elvers began in late November and continued through December reaching a peak in January. The majority of elvers entered the Plenty River trap by night, but during the peak periods elvers were migrating all day.

Relatively small numbers of *Pseudaphritis urvillii* were recorded in the trap from October to February with January being the most important month for upstream movement (fig. 4). These fish varied in size and could not be designated as juveniles.

Only a relatively small number of juvenile *Galaxias brevipinnis* were recorded in this study (n = 97). From the limited data presented in figure 4, the migration appears to correspond closely to that of *Galaxias truttaceus*. The run of juvenile *G. truttaceus* began late in October and finished early in January with the main peak occurring early in November. Although the run of *G. truttaceus* started a little earlier and was of shorter

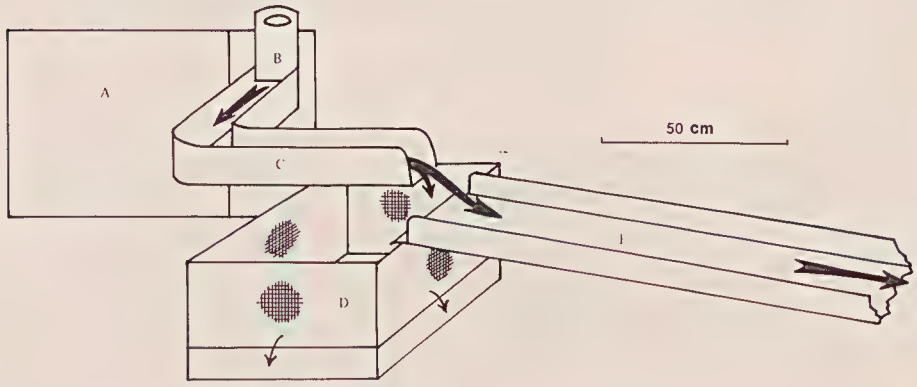

FIG. 3 - Diagram of the Plenty River fish trap showing details of construction. A - blocked off entrance to former fish trap bypass channel; B - sliding control gate to adjust water flow. Flow maintained at approximately 15 l/sec; C - duct carrying water to the trap; D - catching box with 2 mm woven mesh sides; E - rampway leading to the foor of the weir (inclined at 15° and lined with a mat of loosely woven rope and willow branches). The arrows indicate the direction of water flow.

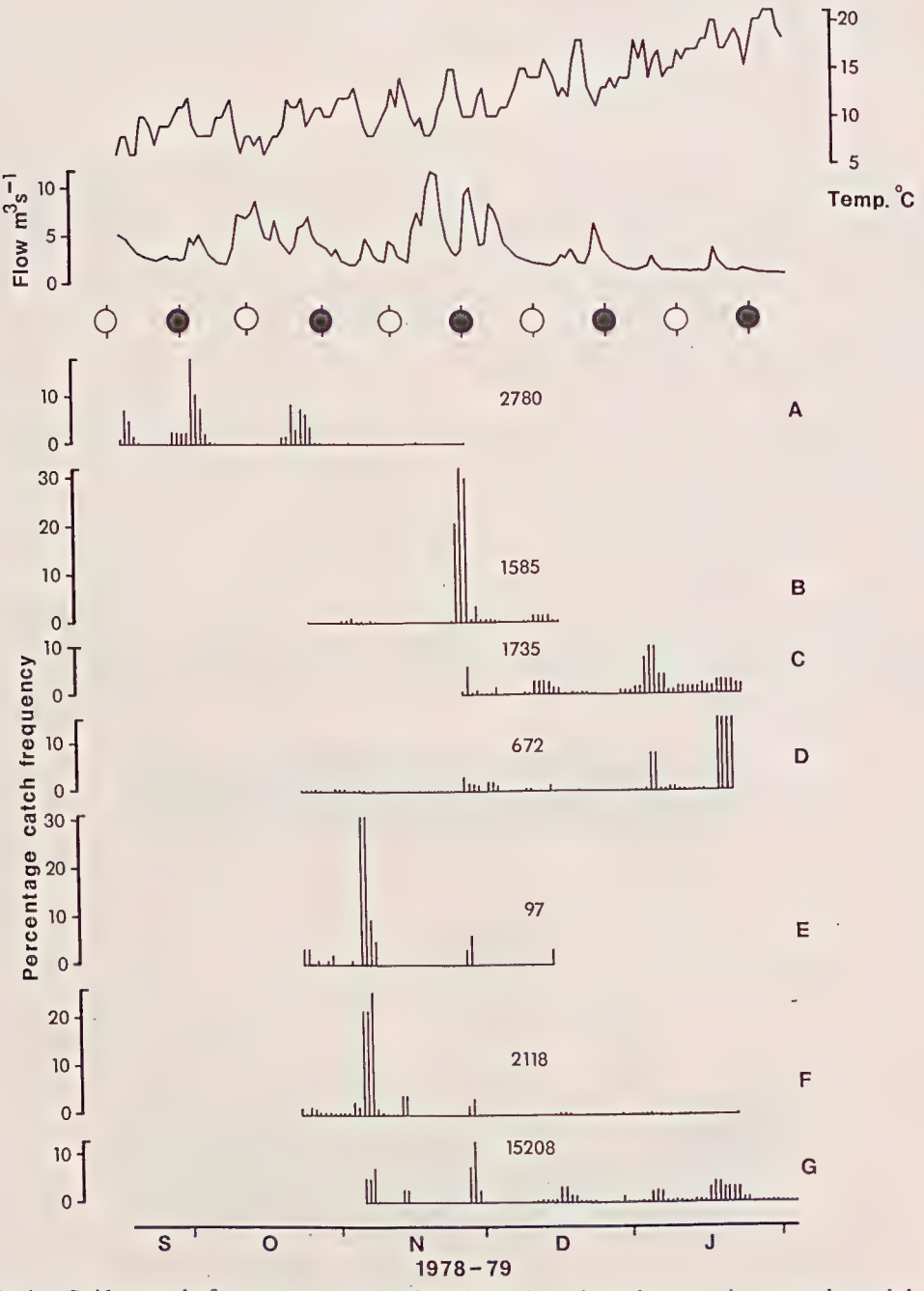

FIG. 4 - Daily catch frequency records for the major migrating species together with daily river flow and morning water temperature records. Days of full moon (open circles) and new moon (solid circles), and the numbers of each species captured, are indicated. Species A *Geotria australis*, B *Mordacia mordax*, C *Anguilla australis*, D *Pseudaphitis urvillii*, E *Galaxias brevipinnis*, F *G. truttaceus*, G *G. maculatus*.

TABLE 1

INCIDENTAL RECORDS FROM THE PLENTY RIVER FISH TRAP.
All the galaxiids recorded in this table were fully pigmented adults and thus were not included in figure 5.

Trapping Period	Numbers	Species
27-28.x.78	1	*Galaxias truttaceus*
29-30.x.78	1	" "
5-7.xi.78	1	*Anguilla australis*
5-7.xi.78	2	*Galaxias maculatus*
10-13.xi.78	1	*Galaxias truttaceus*
27-28.xi.78	5	" "
10-12.xii.78	1	*Gadopsis marmoratus*
12-16.xii.78	2	" "
5-7.i.79	1	*Galaxias truttaceus*
5-7.i.79	18	*Gadopsis marmoratus*
7-9.i.79	3	" "
11-13.i.79	1	" "
19-23.i.79	4	" "
19-23.i.79	2	*Galaxias truttaceus*
19-26.iii.79	3	*Galaxias maculatus*
4-9.iv.79	1	" "
8-14.v.79	1	" "

duration, the peak movements of this species correspond with those of *Galaxias maculatus* over the same period. Large numbers of juvenile *G. maculatus* moved into the trap over an extended period from early November to early February. They were frequently seen moving into the trap during the daylight hours. Only a few adult *G. maculatus* were captured during the trapping period (table 1), lending no support to a returning upstream migration of spent adults as indicated by Scott (1938) and Phillips (1919).

A small number of blackfish, *Gadopsis marmoratus*, were captured during the trapping operation (table 1). The most significant capture was that of 18 blackfish which entered the trap on 6 and 7 January 1979.

Environmental Influences

Water Temperature

Morning (0800 h) water temperature records showed an overall increase from 5°C to 20°C during the main migration season, mid-September to the end of January (fig. 4). All species captured were recorded over a wide temperature range and exhibited no precise temperature preference (fig. 5). The earliest migrant, *Geotria australis*, entered the trap predominantly at stream temperatures between 6°C and 14°C. *Mordacia mordax* was mainly captured at water temperatures between 12°C and 16°C and during the period of its migration, showed a significant ($0.01 < p < 0.05$) positive correlation between water temperature and catch ($r = 0.3159$, 53 days). Similarly, both *Anguilla australis* and *Pseudaphritis urvillii* entered the trap in greater numbers at higher water temperatures; there was a very highly significant ($p < 0.001$) positive correlation between water temperature and catch (calculated for all days during the recorded migration period of each species), for *A. australis* ($r = 0.4450$, 59 days) and for *P. urvillii* ($r = 0.4818$, 91 days). Correlations between water temperature and number of fish captured were not significant ($p > 0.1$) for all other species recorded. *Galaxias brevipinnis* and *Galaxias truttaceus* were generally recorded at water temperatures between 8°C and 16°C whereas the much more extensive migration of *Galaxias maculatus* spanned a wider temperature range, from 8°C to 22°C (fig. 5).

River Flow

The river flow graph is basically a mirror image of the temperature graph (fig. 4) as freshes in the stream correspond with periods of reduced water temperature, consequently these two influences are difficult to separate. As accurate flow recordings were not

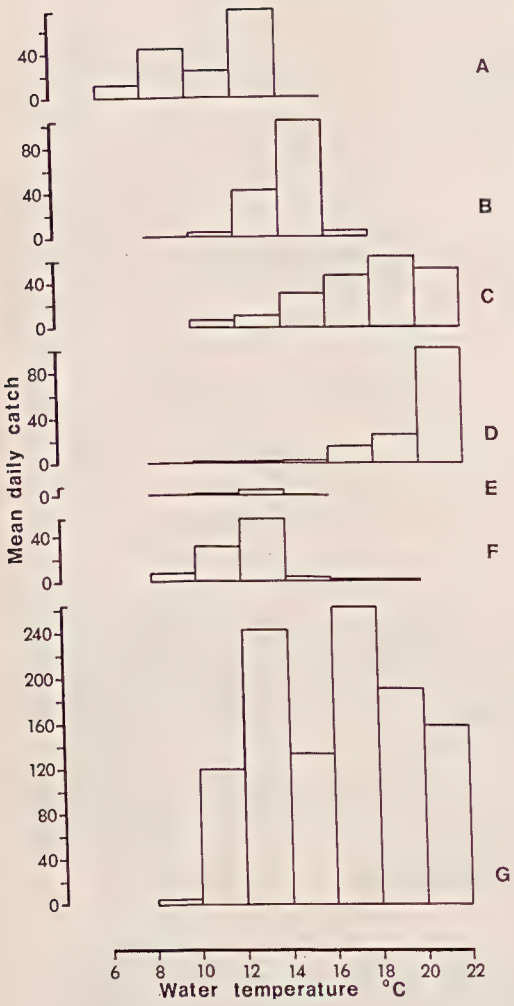

FIG. 5 - Catch data from figure 4 expressed as the number of each species trapped per day at various morning water temperatures (recorded at 0800 h); species as in figure 4.

obtained from the Plenty River, correlations with river flow were not considered to be statistically reliable.

Lunar Period

The percentage catch of each species, arranged by lunar days (fig. 6) shows that peak periods in the upstream movement of several species corresponded with specific lunar periods. The main peak in the catch of *Geotria australis* occurred during the first quarter, soon after the new moon (days 0 to 4) and no lampreys of this species entered the trap during the second lunar quarter. The main movement of *Mordacia mordax* occurred during the last three days of the lunar month. *Anguilla australis* catches were spread throughout the lunar month with a small peak during the second quarter (day 6 to 9). The greatest capture of *Pseudaphritis urvillii* occurred at the beginning of the third quarter (day 21 to 24). *Galaxias* spp. showed a peak in catch during the first lunar quarter (day 5 to 7) with *G. maculatus* exhibiting a second peak at the end of the last quarter.

DISCUSSION

It has been assumed that all the fish recorded during the trapping programme were moving upstream, although the design of the fish trap did not completely exclude the possibility of some fish passing downstream into the catching box. However, the position and size of the upstream entrance relative to the weir, the trash screen position across the entrance and the small fraction of water splashing back into the catching box from the rampway, combined to minimise the possibility. The absence of adult eels, lamprey macrophthalmia and trout fry from the catch support this assumption.

Lampreys entered the Plenty River trap during the hours of darkness and were trapped mainly on dark nights, during the first and last quarters of the moon; such behaviour is generally true of all lamprey migrations (Hardisty & Potter 1971). Potter *et al.* (1968) reported that the migratory movements of *Mordacia mordax* began at dusk, with adults burying themselves deep into the river bed by day. Lynch (1978) reported a run of *Geotria australis* during mid-October at the lower Forth River in northern Tasmania, the same time of year as indicated for southern Tasmania by the present study. In New Zealand, *G. australis* have been observed ascending streams somewhat earlier, with May, June and July being important months for migration (Maskell 1929). Potter *et al.* (1968) determined that spawning run *M. mordax* first enter rivers on the Australian mainland during July and August, with the peak of migration from the beginning of September to the end of November. They suggested the spawning run in Tasmania occurred at approximately the same time. The present study indicates a later, November-December migration for the

Plenty River. The main movement of *M. mordax* into the Plenty River trap occurred during a period of increased water temperature (13°C-15°C) and an associated reduced river flow. This contrasts with the general finding that high water levels are associated with lamprey migrations (Hardisty & Potter 1971).

The upstream migration of *Anguilla australis* took place in the Plenty River during a similar period to the migration recorded by Sloane (1978) at Trevallyn Power Station in northern Tasmania where the run commenced in November and continued until the beginning of February. Beumer & Harrington (1982) considered that the upstream migration season of *A. australis* in the Lerderderg River, Victoria, was just commencing when trapping was discontinued on 2 December. Cairns (1941) and Jellyman (1977) found January and February to be the main months for the migration of *A. australis* elvers in New Zealand. Jellyman (1977) suggested that low water temperatures (less than 10°C) could retard elver migrations. In the Plenty River increased elver catch was related to increased water temperature and reduced river flow.

Conditions of reduced flow and increased water temperature were also associated with the upstream migration of *Pseudaphritis urvillii* in the Plenty River. Although little is known of the life history of this species, two unpublished Tasmanian studies (Sloane 1976, Hortle 1978) indicate an upstream migration phase, with young *P. urvillii* entering fresh water from the estuary or sea. Hortle (1978) suggested progressive upstream movement over a number of years. Lake (1971) made brief mention of migrations of *P. urvillii* in the Murray River, observed during autumn and winter. A compensatory upstream movement of young fish during the summer is suggested by the data presented here.

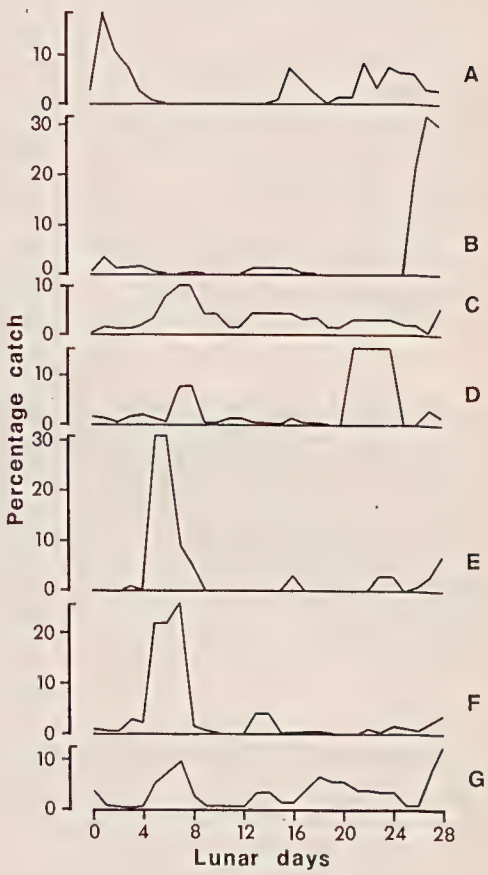

FIG. 6 - Catch data from figure 4, expressed by days in a lunar month (day 0 is the day of the new moon); species as in figure 4.

Scott (1938) studied the movements of *Galaxias maculatus* in Punchbowl Creek, northern Tasmania. He found an extensive juvenile influx in October followed by a less important influx in March. Tasmanian records from 'whitebait' statistics indicate that the initial movement of *G. maculatus* into fresh water occurs mainly in September, October and November (Lynch 1965-72, 1979). In New Zealand, McDowall (1968) found the peak migration period for this species is usually between mid-August and early November. It seems possible that there is a delay of between one and two months between the initial arrival of *G. maculatus* juveniles in the 'whitebait' run and the penetration upstream into fresh water as recorded 9 km above tidal influence at the Plenty River weir. Scott (1941) found migration of juvenile *G. truttaceus* in company with *G. maculatus*, with the main body arriving in late September-early October. September, October and November also appear to be the most important months for *G. truttaceus* in Tasmanian whitebait runs (Lynch 1965-71, 1979). Again, a delay between the arrival of *G. truttaceus* in fresh water and the further upstream penetration is indicated. In Tasmania, *G. brevipinnis* migrations have been observed in

late October by Sloane (1978) at Trevallyn Power Station and by Lynch (1978) at the Forth River weir.

A study on the breeding and early development of the blackfish *Gadopsis marmoratus* (Jackson 1978), gives no indication of a migratory phase in the life history. Jackson (1975) also studied the movements of adult *G. marmoratus* by tagging and he concluded that they exhibit very little movement. It seems likely that the captures of blackfish in the present study represent incidental wanderings rather than any significant migration. Recapture data from tagged *G. marmoratus* led Beumer & Harrington (1982) to conclude that movements of this species through the Lerderberg fish ladder were random.

The absence of brown trout *Salmo trutta* Linnaeus, from the capture data indicates that the flow through the trap was not adequate to attract this species. The subsequent reopening of the salmonid trap at the Plenty River weir resulted in the capture of 70 sea-run brown trout weighing up to 4 kg, during May and June 1982 (Lynch 1982).

CONCLUSION

With the exception of *Geotria australis*, the main months for migration of the species in this study were the summer months of November, December and January. This has important consequences as low river flows at this time may result in even small dams, weirs and culverts becoming effective barriers to migration.

The Plenty River trap illustrates that a bypass channel and/or a simple fish ladder could be used to permit the free upstream passage of a number of migratory fish. With detailed knowledge of the extent and timing of such migrations and some knowledge of the climbing abilities of the species involved, temporary passes or trap and porterage programmes need only be operated for a short period each year to enable migration upstream to adult habitats or spawning grounds.

ACKNOWLEDGEMENTS

Maintenance of the trap, recording of fish numbers and collection of samples were carried out by Mr I. Cameron of the Tasmanian Inland Fisheries Commission Hatchery, 'Salmon Ponds'. The trap was installed as part of a post-graduate study of eel biology being conducted by the author through the Zoology Department, University of Tasmania. Mr B. Rumbold built and installed the trap. Mr W. Fulton assisted with monitoring of the trap and identified the juvenile stages of galaxiids. I would also like to thank Dr R.W.G. White for constructive criticism of the manuscript.

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GENERAL FEATURES OF THE ECOLOGY AND BIOGEOGRAPHY OF TASMANIAN SUBTIDAL ROCKY SHORE COMMUNITIES

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(with two tables, four text-figures and one plate)

ABSTRACT

EDGAR, G.J., 1984 (31 viii): General features of the ecology and biogeography of Tasmanian subtidal rocky shore communities. *Pap. Proc. R. Soc. Tasm.*, 118: 173-186, pl. 1. ISSN 0080-4703. Department of Zoology, University of Tasmania, Hobart, Tasmania, Australia, now C.S.I.R.O., P.O. Box 20, North Beach, Western Australia.

A number of subtidal benthic assemblages of plants and animals which commonly occur around the Tasmanian coast are described. These assemblages are incorporated into a general scheme which relates subtidal zonation patterns to wave exposure and depth.

The existence of a cool-temperate marine biogeographic province (the Maugean), centred in southern, western and eastern Tasmanian waters, is reaffirmed. The biota of the northern Tasmanian coast is considered similar to that of the Victorian coast and includes a large component of Flindersian (Southern Australian) species. A number of Peronian (New South Wales) species reach the Tasmanian east coast. Most of these animals probably drift to Tasmania as pelagic larvae in southward flowing currents, and may even travel further afield to New Zealand, but have difficulty surviving to maturity and spawning. Many Maugean plant and animal species also occur in New Zealand.

INTRODUCTION

A considerable number of studies describing Tasmanian intertidal communities have been reported, notably by Guiler (1952a,b, 1954), Guiler *et al.* (1958), Bennett & Pope (1960), King (1973) and Saenger (1974). By comparison the sublittoral zone has been poorly investigated, despite the widespread availability of SCUBA equipment during the past 20 years. Four algal studies conducted in South Australia (Shepherd & Womersley 1970, 1971, 1976, 1981) represent the only comprehensive ecological studies of subtidal reef habitats in southern Australia. Within the Tasmanian region, published accounts of sublittoral communities are limited to descriptions of benthic algal assemblages in the Port Arthur (Cribb 1954) and D'Entrecasteaux Channel (Edgar 1983a,b) regions, an investigation of the ecology of fishes in soft-bottom habitats (Last 1983), and a descriptive survey of the species of macroalgae and fish which were present at several potential marine park sites around the coast (Edgar 1981). During the course of the latter study, as well as associated surveys carried out since that time, a limited number of assemblages of marine organisms were noticed to recur around the Tasmanian coast. Consequently, a description of these assemblages is published here to allow future studies at particular localities to be related to the overall situation, and to provide a general framework which can then be tested and modified.

A second aim of the present study was to clarify the biogeographic status of the Tasmanian marine biota. The degree of "distinctiveness" of this biota has been the subject of considerable dispute by mainland workers since Iredale & May (1916) proposed the idea of a Maugean biogeographic province centred on the southeast Tasmanian coast. Amongst more recent workers, Bennett & Pope (1960) argued that a separate cool-temperate marine province was well defined in Victoria and Tasmania. Conversely, Womersley & Edmonds (1958) considered that any differences between the Tasmanian and South Australian marine ecosystems are minor and hence the two regions belong to the one biogeographic province. In a later review Womersley (1981) nevertheless noted "whether one province (the Flindersian) is recognized for the whole of southern Australia and Tasmania and whether the south-eastern region

is recognized as a province (the Maugean) or only as a subprovince, depends on what emphasis is placed on a few conspicuous organisms (for example *Durvillaea, Macrocystis*) compared to the whole flora and fauna". Although discussions of biogeographic regions necessarily depend on individual definitions and consequently can be confused, the identification of rapid geographical changes in flora and fauna is nevertheless important both as evidence of present biogeographical barriers and as an indication of past biogeographical processes.

ENVIRONMENTAL CONDITIONS

Hydrology

Mean surface sea temperatures off southeastern Tasmania vary from about 12°C in August to about 17°C in February (Edwards 1979). Temperatures in Bass Strait are generally about 2°C warmer. Conditions inshore are much more dependent on local atmospheric conditions. Temperatures within shallow bays usually vary from about 8°C in winter to about 22°C in summer, and can decline as low as 2°C and rise above 27°C (Thomson *et al.* 1982).

The salinities of coastal waters are relatively constant during the year, varying from about 35.1‰ to about 35.4‰ (Edwards 1979). The levels of nutrients in Tasmanian seas are poorly known (Rochford 1974, 1979) but are unlikely to decline sufficiently to limit the growth of inshore marine life.

Currents

Marine waters along the eastern Tasmanian coast flow southward under the influence of the East Australian Current. Warm core eddies, which break from East Australian Current meanders, may occasionally reach inshore Tasmanian waters. These discrete water bodies are about 3°C warmer than surrounding seas and generally move southward from the southern New South Wales coast and then eastward towards New Zealand (Nilsson & Cresswell 1981). Currents along the Tasmanian west coast were thought by Newell (1960) to flow in a northeasterly direction during the summer months and then reverse direction to flow southeastward during winter. However, Baines *et al.* (1983) described a west coast current, named the Zeehan Current, which varied seasonally in strength but flowed southward throughout the year.

Tidal standing waves located at the east and west entrances to Bass Strait were postulated by Pollock (1971) to restrict the movement of surface water from the Bass Strait basin for a large part of the year. A cascade of deep saline water nevertheless flows from Bass Strait along the eastern Victorian coastline during winter months (Godfrey *et al.* 1980).

Tides

Mean tidal heights at selected localities around the Tasmanian coast, as listed in the Australian National Tide Tables (Dept of Defence 1977), are shown in table 1. Tidal ranges are relatively large (exceeding 2.5 m) in western Bass Strait but decline to 2.0 m in eastern Bass Strait and are less than a metre in most other areas of the State. The meteorological influences on sea level changes along the microtidal southern and western coasts may be equal to the solar and lunar influences (Matthews 1978).

Sea State

Bennett & Pope (1960) and Davies (1978) discussed the exposure of different Tasmanian coasts to wind and waves. The exposure classification scheme described by Bennett & Pope (1960) is used in the present study. Using this scheme, reefs on the west coast with direct wave action are classed as maximally exposed and those on the east coast as submaximally to maximally exposed. The northern Tasmanian shore is generally classed as a sheltered open coast, however a few reefs in southwestern and southeastern Bass Strait with slightly greater wave exposure, such as Rocky Cape, are classed as moderately exposed.

TABLE 1

MEAN TIDAL HEIGHTS AT SELECTED TASMANIAN LOCALITIES.
Data from Department of Defence (1977).

	Tidal Height			
	MHHW	MLHW	MHLW	MLLW
Grassy, King Island	1.4	0.7	0.6	0.0
Stanley	3.6	3.0	1.3	0.8
Georgetown	3.1	3.1	1.0	0.6
Winter Cove, Kent Group	2.3	2.2	0.6	0.2
Lady Barron, Flinders Island	1.6	1.6	0.7	0.5
Waterhouse Island	2.3	2.2	0.6	0.2
Swan Island	1.6	1.4	0.5	0.2
Hobart	1.4	1.2	0.9	0.5
Maatsuyker Island	0.9	0.8	0.8	0.4
Cape Sorell	0.9	0.8	0.7	0.4

METHODS

General information relating to the depth and distribution of macro-algae and fish was recorded on underwater notepads during SCUBA dives at various reefs around the northern, eastern and southern coasts of Tasmania, and the eastern Bass Strait islands (fig. 1). The western Tasmanian coast and King Island were not investigated.

The similarities in reef fish fauna between different sites were compared using Sorenson's similarity coefficient (Southwood 1966), which was calculated as follows

$$S = 2c/(a+b)$$

where a is the number of fish species sighted at location 1; b is the number of species sighted at location 2; and c is the number of fish in common to the two locations.

Fish species generally found on sedimentary substrata, such as urolophids and platycephalids, and cryptic species, such as gobiids, clinids, tripterygiids and gobiesocids, were not considered in these analyses.

RESULTS AND DISCUSSION

Effects of Wave Exposure and Depth

Despite an overlap of species near the boundaries of different assemblages, the locations of the major assemblages of benthic organisms along the eastern, southern and western Tasmanian coasts can be predicted reasonably accurately by reference to wave exposure and depth (fig. 2). The benthic assemblages in Bass Strait are less well defined but approximately follow the same classification. The dominant species of plants and animals within these assemblages are as follows:

Durvillaea Assemblage

The sublittoral fringe and upper sublittoral zone on exposed coasts are colonized by monospecific stands of *Durvillaea potatorum* (Labill.) Aresch. (plate 1a). *Xiphophora gladiata* (Labill.) Mont. ex Kjell, and to a lesser extent *Lessonia corrugata* Lucas, also occur in this zone. *Xiphophora* often forms a narrow band above the *Durvillaea* belt, particularly in moderately exposed areas, and is also occasionally present at the interface between the *Durvillaea* and *Lessonia/Phyllospora* zones. It is likely that *Xiphophora* and other macroalgae are capable of growing at wave-swept sites but are outcompeted by *Durvillaea*, presumably because the whiplash motion of *Durvillaea* prevents the settlement and/or growth of the other algal species. This hypothesis, which contrasts with the situation in Chile where Santelices *et al.* (1980) found that *Lessonia nigrescens* outcompeted *Durvillaea antarctica*, is supported by the fact that cleared patches within the *Durvillaea*

FIG. 1 - Map of Tasmania showing localities mentioned in the text.

zone are colonized almost exclusively by *Durvillaea* sporelings, indicating that other species are prevented from settling or are less rapid colonizers. Moreover, *Durvillaea* is restricted to a very narrow zone in regions with steeply sloping substrata where the plants experience little vertical frond motion. It is notable that the *Durvillaea* zone on a gently sloping reef east of isolated Eddystone Rock (25 km SE of the southern coast) extends to 18 m depth with individual plants occurring at 30 m, while other large brown algae (*Lessonia corrugata*, *Ecklonia radiata* (C.Ag) J.Ag., *Phyllospora comosa* C.Ag., *Xiphophora gladiata* and *Macrocystis pyrifera* (L.) C.Ag.) were also present but were restricted to deep water (>18 m).

Cystophora torulosa Assemblage

Cystophora torulosa (R.Br.) J.Ag. is the dominant plant in the lower eulittoral zone, and also occurs rarely in a sublittoral fringe, in most areas with insufficient wave exposure for the growth of *Durvillaea potatorum*. A band of *Hormosira banksii* (Turn.) Dec. generally occurs above *Cystophora torulosa*, particularly in the more sheltered regions.

Lessonia/Phyllospora Assemblage

Either *Lessonia corrugata* or *Phyllospora comosa* plants generally dominate the reef substratum below the *Durvillaea* zone (plate 1c). Field experiments are needed to deduce the factors resulting in the near-exclusion of one or the other of these species because it is difficult to predict which of the two species will be most conspicuous in any area. At Cape Queen Elizabeth on the exposed coast of Bruny Island, for example, *Lessonia corrugata* is the dominant algae at depths between 3 and 7 metres while *Phyllospora comosa* is rare, however 30 km south at Cape Bruny *Phyllospora* is the dominant species at similar depths. The two species, nevertheless, appear to differ slightly in some of their physical preferences; *Lessonia* preferring marginally shallower water, cooler water temperatures and a more steeply sloping rock substratum than *Phyllospora*.

Ecklonia/Mixed Algal Assemblage

The presence of *Ecklonia radiata* plants is possibly the only unifying feature of this assemblage which is otherwise difficult to characterize because of the diversity of the flora. *Ecklonia radiata* is the dominant species below the *Lessonia/Phyllospora* assemblage in exposed regions (plate 1b), but becomes a relatively minor constituent of a mixed algal assemblage in more sheltered habitats (with *Acrocarpia paniculata* (Turn.) Aresch., *Seirococcus axillaris* (R.Br.) Grev., *Cystophora retorta* (Mert.) J.Ag., *Carpoglossum confluens* (R.Br.) Kutz., *Halopteris* spp., *Codium* spp., *Jeannerettia lobata* Hook. & Harv., *Plocamium angustum* (J.Ag.) Hook. & Harv., *Melanthalia obtusata* (Labill.) J.Ag., *Phacelocarpus labillardieri* (Mert.) J.Ag. and *Hemineura frondosa* Harv., and also *Cystophora monilifera* J.Ag., *C. polycystidea* Aresch., *C. subfarcinata* (Mert.) J.Ag., *Macrocystis*

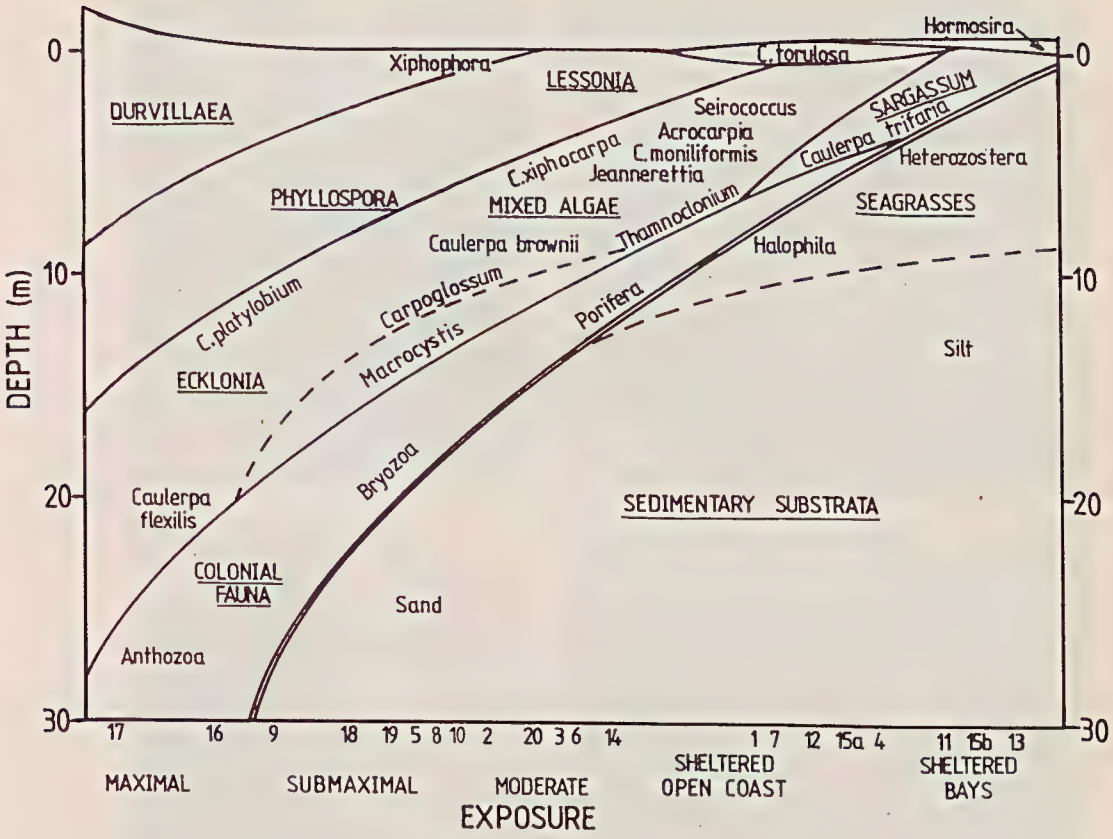

FIG. 2 - Generalized scheme showing the distribution of different benthic assemblages in Tasmania. The names of the conspicuous organisms are shown in the position of depth and exposure at which they are most abundant, however many of these species are found in other environmental conditions. The *Phyllospora/Lessonia* assemblage is incorporated within the *Ecklonia*/mixed algal assemblage in Bass Strait.

The wave exposure of the sites surveyed during this study are shown along the abscissa where Site 1 is Garden Cove, Deal Is., Kent Group; Site 2 is the southwestern point of Erith Is., Kent Group; Site 3 is Palana, Flinders Island; Site 4 is Tongue Point, Flinders Island; Site 5 is North West Cape, Three Hummock Is.; Site 6 is Rocky Cape; Site 7 is Cape Portland; Site 8 is Eddystone Point; Site 9 is Merrick Rocks near St Helens; Site 10 is Fossil Cliffs, Maria Is.; Site 11 is Encampment Cove, Maria Is.; Site 12 is Tinderbox, D'Entrecasteaux Channel; Site 13 is Woodbridge, D'Entrecasteaux Channel; Site 14 is Ninepin Point, D'Entrecasteaux Channel; Site 15a is a semi-exposed site and Site 15b a sheltered site, Fancy Point, Bruny Is. (Edgar 1983a,b); Site 16 is Cape Queen Elizabeth, Bruny Is.; Site 17 is Cape Bruny, Bruny Is.; Site 18 is Shoemaker Bay, South Coast; Site 19 is Maatsuyker Is.; Site 20 is Breaksea Is., Port Davey; and Site 21 is Eddystone Rock.

angustifolia Bory, *Sargassum heteromorphum* J.Ag. and *Scaberia agardhii* Grev. in Bass Strait). Most of the brown algal species in sheltered habitats extend only to moderately exposed coasts, while sheltered red algal species range further and also generally occur on maximally exposed coasts at the same depths as *Ecklonia*. A number of other codominant species belonging to the *Ecklonia*/mixed algal assemblage are most abundant in regions with particular environmental conditions (notably *Caulerpa flexilis* Lamaroux and *Thamnoclonium*

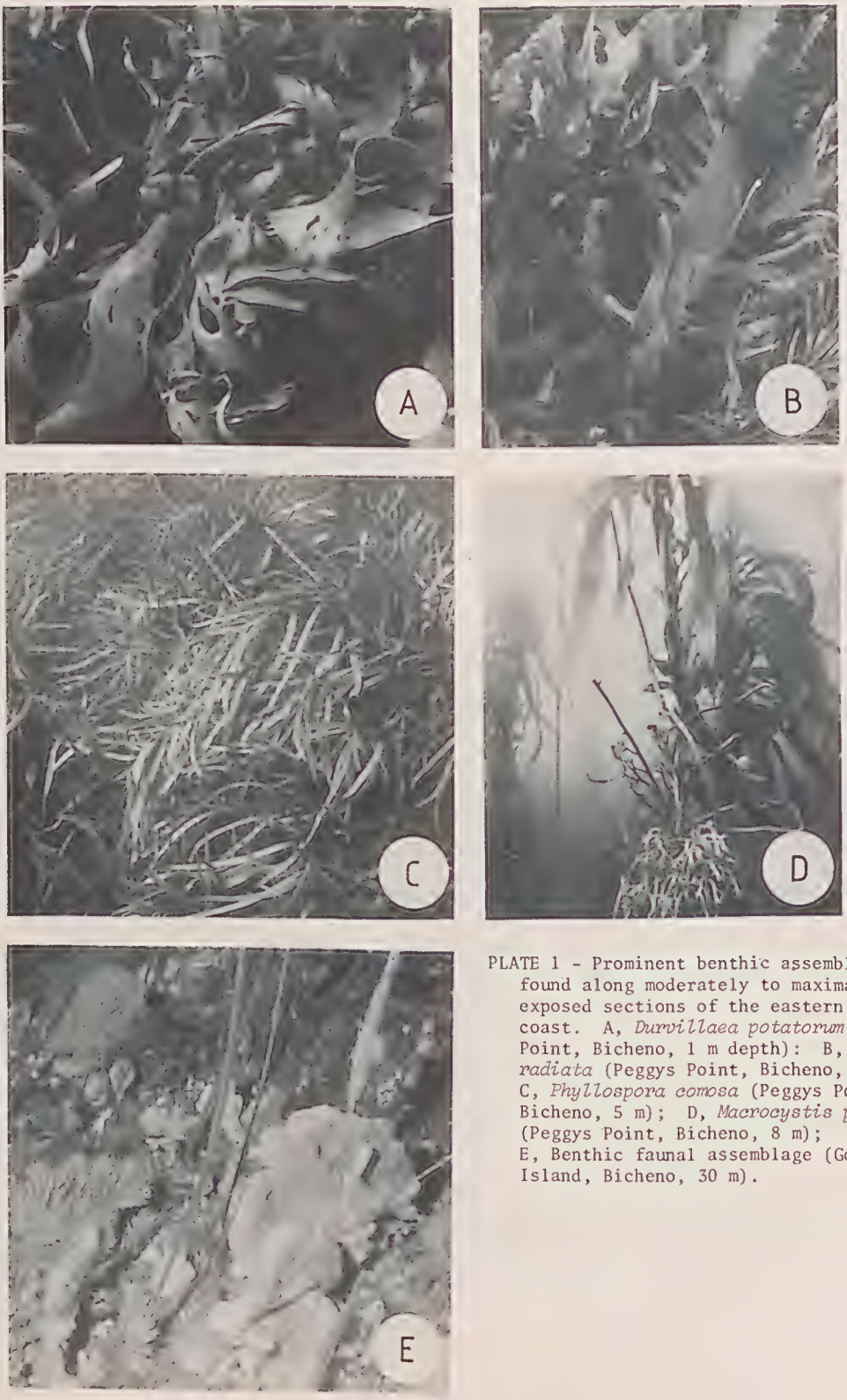

PLATE 1 - Prominent benthic assemblages found along moderately to maximally exposed sections of the eastern Tasmanian coast. A, *Durvillaea potatorum* (Peggys Point, Bicheno, 1 m depth): B, *Ecklonia radiata* (Peggys Point, Bicheno, 7 m); C, *Phyllospora comosa* (Peggys Point, Bicheno, 5 m); D, *Macrocystis pyrifera* (Peggys Point, Bicheno, 8 m); E, Benthic faunal assemblage (Governor Island, Bicheno, 30 m).

sp. in deeper water, *Cystophora platylobium* (Mert.) J.Ag. in maximally or submaximally exposed areas, *C. xiphocarpa* in moderately exposed, sand scoured areas, and *Caulerpa brownii* (C.Ag.) Endl. on vertical or steeply sloping rock faces). Another locally common species, *Macrocystis pyrifera*, is dominant in depths of 8 to 22 m in submaximally or moderately exposed regions with horizontal substrata (plate 1d). *Macrocystis* fronds form a dense canopy which modifies the benthic algal community by shading the reef and consequently preventing large brown algae, other than an occasional *Ecklonia* plant, from growing. One further species of interest within the *Ecklonia*/mixed algal assemblage is *Cystophora moniliformis* (Esper) Wom. which grows in a variety of physically stressed areas but appears to be outcompeted for space in more favourable habitats. *C. moniliformis* is most abundant on sand scoured reefs, including those covered by several centimetres of sediment (see Shepherd & Womersley 1981), and in the sublittoral fringe below *C. torulosa*.

Sargassum Assemblage

This sheltered assemblage is characterized by the codominant Fucales *Sargassum bracteolosum* J.Ag., *S. verrucolosum* (Mert.) J.Ag., *Cystophora retroflexa* (Labill.) J.Ag. and *Caulocystis cephalornithos* (Labill.) Aresch. with small *Zonaria turneriana* J.Ag. plants also occurring in high densities but being relatively inconspicuous (Edgar 1983b). The rhizomatous green alga *Caulerpa trifaria* Harv. is often present with the deeper fucoid algae but is not restricted to the *Sargassum* assemblage because it also extends into the benthic faunal assemblage and is found at exposed locations in the *Ecklonia*/mixed algal assemblage. In Bass Strait waters *Scaberia agardhii* generally also occurs within the *Sargassum* assemblage, *Sargassum bracteolosum* and *Cystophora retroflexa* are not very conspicuous, and *Caulocystis cephalornithos* is often replaced by *C. uvifera* (C.Ag.) Aresch.

Benthic Faunal Assemblage

In sheltered, turbid conditions a benthic faunal community is present below the *Sargassum* assemblage, but has a low diversity because very few sedentary animal species survive amongst the fine sediment which coats the reefs (the sponge *Phyllospongia caliciformis* Carter being one exception). However, a diverse benthic animal assemblage of sponges, gorgonians (such as *Mopsea whiteleggei* Thomson & Mackinnon, *Acabaria* sp. and *Primnoella australasiae* Gray), alcyonarians (including *Capnella erecta* Verseveldt), ascidians, bryozoans and hydroids is found in deeper, more exposed areas (plate 1e). A number of red algal species (e.g. *Sonderopelta coriacea* Wom. & Sinkora and *Thamnoclonium* sp.) are found in the shallower sections of the benthic faunal assemblage. The minimum depth of this assemblage depends on the maximum depth at which fucoid and laminarian algal species grow and is thus primarily dependent on water clarity. In southern Tasmania at locations near the mouths of such rivers as the Huon, Old and Davey (e.g. Ninepin Point in D'Entrecasteaux Channel and Breaksea Island in Port Davey) the benthic faunal assemblage occurs at a much shallower depth than predicted in figure 2. At these sites a surface layer of darkly stained, tannin-rich, estuarine water greatly restricts light penetration to the fully marine waters at depth, particularly during the winter months. At Breaksea Island, for example, *Durvillaea potatorum* extends to 2 m, *Phyllospora* to 3 m, the *Ecklonia*/mixed algal assemblage to 5 m, and then the benthic faunal assemblage to the edge of the reef at 16 m depth.

Effects of Latitude

The depth ranges of the *Durvillaea* and *Lessonia/Phyllospora* assemblages increase with latitude. The *Durvillaea* zone at Merrick Rock near St Helens on the northeastern coast, for example, extends to a depth of only 1 m, whereas at places with similar exposure on the southern coast *Durvillaea* is dominant to 3 or 4 m depth. As noted previously, *D. potatorum* is present at 30 m depth at Eddystone Rock off the south coast. Moreover, *Durvillaea* occurs in sheltered habitats in Port Davey (for example Bramble Cove) but is not found at moderately exposed locations on the Tasmanian north coast (for example Rocky Cape). *Durvillaea* is also absent from the submaximally exposed coast of Deal Island, although it occurs at Wilsons Promontory, Victoria, and Palana, Flinders Island. *Lessonia corrugata* is not present on many Bass Strait reefs and *Phyllospora comosa* plants often do not form a distinctive assemblage but occur within the *Ecklonia*/mixed algal assemblage.

The fish fauna also varies with latitude. The number of fish species sighted during half-hour diving transects decreases significantly from Bass Strait to the east coast and southern Tasmania (fig. 3), presumably because many warm-temperate species cannot survive in the cool waters off the south coast.

Biogeography

The similarity matrix presented in figure 4 shows the degree of association between the reef ichthyofaunas at the Investigator Group (South Australia), Wilsons Promontory (Vic.), Avalon (N.S.W.) and different regions around Tasmania. A list of the fish species sighted during the study in the various Tasmanian regions is given in appendix 1. Despite small sample sizes at Avalon and Wilsons Promontory, which tend to reduce the level of similarity, it appears that southern Tasmania, South Australia and New South Wales have markedly different reef fish assemblages. On the basis of these reef fish distributions, plus additional observations in Tasmania, it is useful to consider that a Maugean marine province exists and is centred in southern, western and eastern Tasmania. Bass Strait comprises an overlap area, primarily between Maugean and Flindersian (South Australian) species.

A large proportion of the Flindersian plants (e.g. *Sargassum heteromorphum*, *Cystophora monilifera*, *C. polycystidea*, *C. botryocystis* Sond., *Scaberia agardhii* and *Posidonia australis* Hook. f. Black) and animals (e.g. *Meuschenia hippocrepis* (Quoy & Gaimard), *M. flavolineata* Hutchins, *Platycephalus speculator* Klunzinger, *Aracana ornata* (Gray) and *Parma victoriae* (Günther)) are widespread in Bass Strait but are very rarely if ever found further south. The great reduction in Flindersian species from Bass Strait to the Tasmanian east coast, which causes very pronounced changes in the plant and animal assemblages over 25 km distance from Cape Portland to Cape Musselroe, is most likely due to increased wave exposure and decreased water temperatures. This change in biota in north-eastern Tasmania, and a similar change around the northwestern corner of Tasmania, is probably much greater than changes in marine communities over comparable distances at other biogeographical boundaries around the Australian coast. Nevertheless, several Flindersian species penetrate in reduced numbers along the east coast, and a large proportion of these reach Maria Island (for example the seagrass *Amphibolis antarctica* (Labill.) Sond. & Asch. and the fishes *Melambaphes zebra* (Richardson), *Olistops cyanomelas* Richardson and *Neoodax beddomei* (Johnston)). It is notable that, as well as these Flindersian species, a number

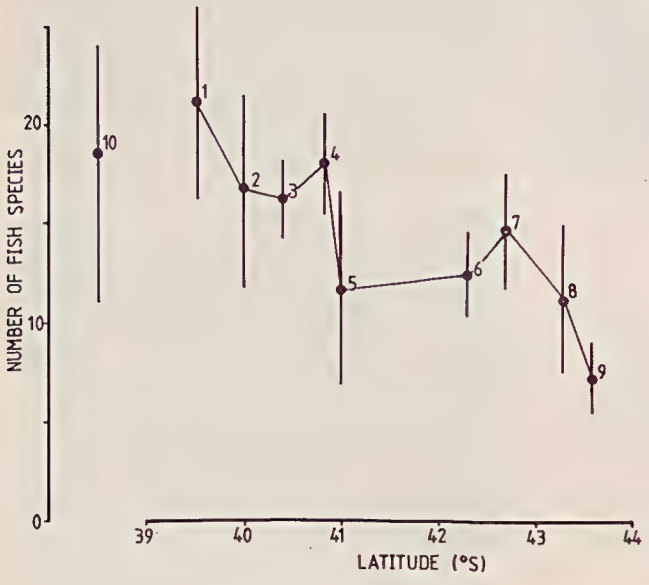

FIG. 3 - Relationship between latitude and the mean number (± standard deviation) of fish species sighted during a half-hour diving period at moderately to submaximally exposed sites in different regions of Tasmania. Regions are as follows:

1 Kent Group
2 Flinders Island
3 Three Hummock Island
4 Rocky Cape
5 Northeast (Bicheno to Eddystone Point)
6 Freycinet Peninsula and Schouten Island
7 Maria Island
8 Bruny Island
9 South Coast
10 Investigator Group, South Australia.

of species of planktonic crustacea (Nyan Taw 1975), infaunal cumacea (Dartnall 1981) and Peronian (New South Wales) reef species (e.g. the fishes *Girella elevata* Macleay and *Atypichthys strigatus* (Günther) and the echinoid *Centrostephanus rodgersii* Agassiz), also are rare or absent south of approximately the latitude of Maria Island. Nyan Taw (1975) considered that this faunal boundary resulted from a change in hydrological conditions.

Peronian reef species are only conspicuous in Tasmania at the Kent Group, the southernmost site where the fishes *Aptychotrema rostrata* Shaw & Nooder, *Chromis hysilepis* (Günther) and *Opthalmolepis cyanogramma* (Cuvier & Valenciennes) have been recorded, and to a lesser extent the Furneaux Group, particularly the east coast of Flinders Island, and along the northeastern Tasmanian coast. A few species (e.g. *Atypichthys strigatus* and *Parma microlepis* Günther) also penetrate to western Bass Strait.

It is likely that few Peronian animals successfully spawn in Tasmanian waters and that the distribution and abundance of most Peronian species are dependent on the survival of pelagic larvae spawned in N.S.W. and the vagaries of the East Australian Current because (i) the number of species and individuals decreases markedly with increasing latitude, (ii) adult Peronian fish are numerically insignificant compared to juveniles, and (iii) the abundance of many Peronian animal species varies greatly from year to year (for example the recruitment of the rock lobster *Jasus verreauxi* (H. Milne-Edwards) at Flinders Island; and the prawn *Penaeus plebejus* Hesse at North East River estuary, Flinders Island, and Georges Bay, northeastern Tasmania). Moreover, some Peronian species probably have become much more conspicuous in Tasmania over the past 20 years, during a period when sea temperatures along the eastern Tasmanian coast have risen (by an average of 1.5°C at Maria Island, Rochford 1981). The lower eulittoral barnacle *Megabalanus nigrescens* (Lamarck) appears to be one such species as it is now abundant at many places on the Tasmanian east coast including Eddystone Point and Eaglehawk Neck, while 24 years ago Bennett & Pope (1960) considered that the species "fails to bridge the gap across Bass Strait" despite collecting intensively at those two east coast localities.

Most species with clear Maugean affinities are widespread around the Tasmanian coast, although several species (for example the plants *Gigartina ancistroclada* Mont., *Macrocystis pyrifera* and *Xiphophora gladiata* and the fish *Mendesoma allporti* Johnston) are absent from northern reefs. A large proportion of Maugean animals (viz. 42% of the fish species recorded in this study from the southern Tasmanian coast and Port Davey) and plants (e.g. *Cystophora torulosa*, *Adenocystis utricularis* (Bory) Skottsberg and *Macrocystis pyrifera*) also occur in similar latitudes in New Zealand. Many Peronian as well as Maugean species are also common in New Zealand. However Flindersian species are notably absent. A considerable number of organisms thus appear to have dispersed across the Tasman Sea in recent times because

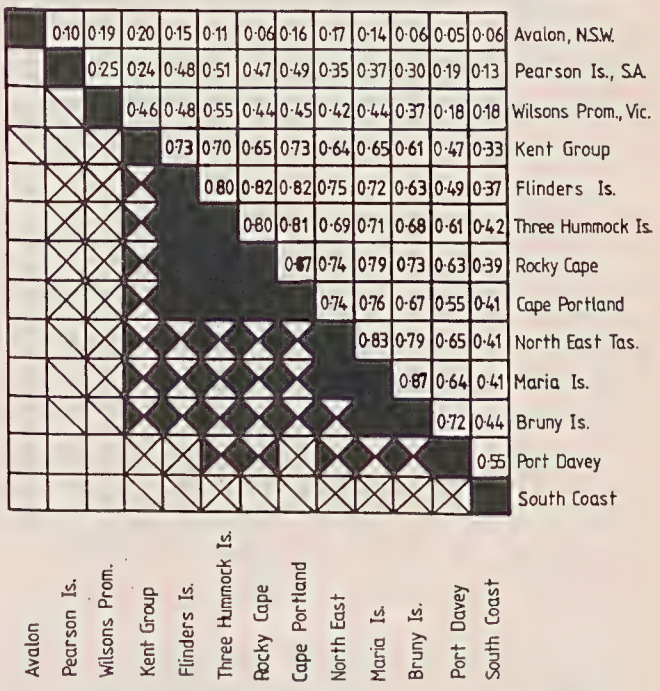
0·10 0·19 0·20 0·15 0·11 0·06 0·16 0·17 0·14 0·06 0·05 0·06 Avalon, N.S.W.
0·25 0·24 0·48 0·51 0·47 0·49 0·35 0·37 0·30 0·19 0·13 Pearson Is., S.A.
0·46 0·48 0·55 0·44 0·45 0·42 0·44 0·37 0·18 0·18 Wilsons Prom., Vic.
0·73 0·70 0·65 0·73 0·64 0·65 0·61 0·47 0·33 Kent Group
0·80 0·82 0·82 0·75 0·72 0·63 0·49 0·37 Flinders Is.
0·80 0·81 0·69 0·71 0·68 0·61 0·42 Three Hummock Is.
0·87 0·74 0·79 0·73 0·63 0·39 Rocky Cape
0·74 0·76 0·67 0·55 0·41 Cape Portland
0·83 0·79 0·65 0·41 North East Tas.
0·87 0·64 0·41 Maria Is.
0·72 0·44 Bruny Is.
0·55 Port Davey
South Coast
Avalon
Pearson Is.
Wilsons Prom.
Kent Group
Flinders Is.
Three Hummock Is.
Rocky Cape
Cape Portland
North East
Maria Is.
Bruny Is.
Port Davey
South Coast

FIG. 4 - Matrix depicting the similarity of the non-cryptic reef fish species which were sighted during the present survey between different regions of Tasmania and southeastern Australia.

divergence and differentiation of isolated populations would be expected to have occurred during the period of more than 55 million years (Kennett 1977) since Australia separated from Gondwanaland. Recruitment of larval fish to New Zealand, presumably partly from Australia with assistance from the East Australian Current, was considered by Willan *et al.* (1979) to account for many of the tropical and subtropical fish species present in northern New Zealand.

Much of the disagreement about the merits of a Maugean biogeographic region has arisen because of the cool-temperate nature and low diversity of Tasmanian seas. At the north-eastern study sites, for example, the number of Maugean fish species is comparable to the numbers of Flindersian and Peronian species. However, the Maugean species are represented by many more individuals and numerically dominate the ecosystems. Also, the Flindersian species at these sites comprise only a very small component of the total fauna in the Flindersian province while a large proportion of species in the Maugean province are represented.

Womersley's (1959) criticisms of the Maugean biogeographic province, which were based on the total marine flora of southern Australia, nevertheless still have some validity because differences between the temperate marine provinces become increasingly obscured with depth. Organisms within the intertidal zone and sublittoral fringe are much more localized in distribution than sublittoral and deeper water species (table 2). Few of the dominant subtidal benthic reef species in southern Tasmania are endemic to the Maugean region, and thus the cool-temperate marine province is not greatly distinctive if these organisms rather than reef fishes or intertidal species are considered.

In summary, providing differences rather than similarities between biogeographic regions are stressed, the shallow water biota in southern Tasmania is sufficiently distinctive to comprise a depauperate Maugean marine province. Many of the Maugean species have considerable dispersal ability, as is evident by their presence in New Zealand, but are restricted, presumably by water temperatures rather than biogeographic barriers, to the Tasmanian, Victorian and southeastern South Australian (to Cape Jaffa) regions in Australia. Conversely, Flindersian and Peronian species generally appear capable of dispersing to southern Tasmania but many of these species are unable to survive or reproduce within the region.

Dartnall (1974) suggested that the southern and eastern Australian biotas were isolated from each other during periods when Tasmania was connected by landbridge to the Australian mainland. This hypothesis is reinforced by the present study because the colder water temperatures during past ice ages would have allowed very few species to pass around the southern Tasmanian coast. Extant species pairs which presumably differentiated during such periods of isolation include the fish *Arripis esper* Whitley/*A. trutta* (Bloch & Schneider), *Upeneichthys lineatus* (Bloch & Schneider)/*U. vlamingii* (Cuvier & Valenciennes), *Paraplesiops meleagris* (Peters)/*P. bleekeri* (Günther) and *Scorpis aequipinnis* Richardson/*S. lineolatus* Kner. Algae do not show similar sibling species pairs, however, and may require longer periods of isolation for the genetic divergence of isolated populations.

Past vicariant events (i.e. sea level changes resulting in Tasmania/Australia landbridges) thus appear to have separated the Flindersian and Peronian regions, resulting in allopatric speciation and allowing a high diversity of organisms in southern Australia to develop. The separation of the Maugean region, on the other hand, is probably due to water temperature and wave exposure barriers which operate at present on individual species.

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TABLE 2

SPECIES FOUND ABUNDANTLY IN SOUTHERN TASMANIAN COASTAL WATERS BETWEEN SOUTH EAST CAPE AND SOUTH WEST CAPE.

Flora	Fauna
Eulittoral Species	
*Gigartina ancistroclada**	*Littorina praetermissa** (May)
*Lithophyllum hyperellum**	*Cominella lineolatus** (Lamarck)
	*Notoacmaea mayi** May
	*Lepsiella vinosa** (Lamarck)
	*Siphonaria tasmanica** T-Woods
	*Siphonaria diemenensis** Quoy & Gaimard
	Patelloida latistrigata (Angas)
	Cellana solida (Blainville)
	*Patellanax peroni** (Blainville)
	Sypharochiton pelliserpentis (Quoy & Gaimard)
	*Brachidontes rostratus** (Dunker)
	Chamaesipho columna (Spengler)
	Catomerus polymerus (Darwin)
	*Cyclograpsus granulosus** (M-Edwards)
Sublittoral Fringe and Rock Pool Species	
*Cystophora xiphocarpa**	*Patiriella exigua* (Lamarck)
*Durvillaea potatorum**	*Patelloida victoriana** (Singleton)
*Xiphophora gladiata**	*Poneroplax costata* (Blainville)
Caulerpa brownii	*Ischnochiton subviridus* (Iredale & May)
	Actinia tenebrosa Farquhar
	Naxia aurita (Latreille)
	*Paragrapsus quadridentatus** (M-Edwards)
Sublittoral Species (>5 m depth)	
Cystophora platylobium	*Austrofromia polypora* (Clark)
Phyllospora comosa	*Petricia vernicina* (Lamarck)
Ecklonia radiata	*Nectria ocellata* Perrier
*Macrocystis pyrifera**	*Haliotis ruber* Leach
Caulerpa brownii	*Jasus novaehollandiae* Holthuis
Carpoglossum confluens	*Plagusia chabrus* (Linnaeus)
Melanthalia obtusata	*Dicathais baileyana* T-Woods
Thamnoclonium clariferum	
*Lessonia corrugata**	

* Species very rarely if ever found within Australian waters outside Tasmania and the region from Robe, South Australia to Bermagui, N.S.W.

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APPENDIX 1

NON-CRYPTIC REEF FISH SPECIES SIGHTED WITHIN VARIOUS INVESTIGATED REGIONS.

1: Kent Group
2: Furneaux Group
3: Three Hummock Island
4: Rocky Cape
5: Cape Portland
6: North East Coast (Eddystone Point to Bicheno).
7: Maria Island
8: Bruny Island
9: Port Davey
10: South Coast

Species	Region 1	2	3	4	5	6	7	8	9	10
Heterodontus portusjacksoni (Meyer)	x	x		x	x		x			
Parascyllium ferrugineum McCulloch*	x							x	x	
Cephaloscyllium laticeps (Dumeril)*	x	x	x	x	x	x	x	x		
Myliobatis australis Macleay				x	x		x			
Conger verreauxi Kaup*				x		x	x	x		
Lotella rhacinus (Forster)	x					x	x	x		
Pseudophycis bachus (Bloch & Schneider)		x		x	x	x	x	x	x	
Pseudophycis barbata Günther			x	x	x	x	x	x	x	x
Optivus elongatus Günther*	x									
Paratrachichthys traili (Hutton)*				x		x	x	x	x	
Cyttus australis (Richardson)*							x	x		
Solegnathus spinossimus Günther*							x	x		
Hippocampus abdominalis Lesson						x	x	x	x	
Phyllopteryx taeniolatus Lacepede*						x	x	x		
Helicolenus papillosus (Bloch & Schneider)*				x			x		x	
Neosebastes scorpaenoides Guichenot*			x	x		x	x	x	x	
Scorpaena ergastulorum Richardson*	x	x	x	x	x	x	x	x	x	
Gnathanacanthus goetzii Bleeker			x				x	x		
Caesioperca lepidoptera (Bloch & Schneider)	x	x				x	x	x		x
Caesioperca rasor (Richardson)	x	x	x	x		x	x	x	x	
Callanthias allporti Günther						x				
Ellerkeldia maccullochi Whitley	x									
Hypoplectrodes nigrorubrum Cuvier		x		x						
Trachinops caudimaculatus McCoy*	x	x	x	x	x	x	x	x	x	x
Dinolestes lewini (Griffith)	x	x	x	x	x	x	x	x	x	x
Vincentia conspersa (Klunzinger)	x	x	x	x	x	x	x	x	x	
Pseudocaranx dentex Bloch & Schneider	x	x				x				
Seriolella brama Günther	x									
Trachurus declivus (Jenyns)				x	x	x	x	x		
Arripis trutta (Bloch & Schneider)		x		x	x	x	x	x		x

Species	Region 1	2	3	4	5	6	7	8	9	10
Parequula melbournensis (Castelnau)	x	x	x	x	x	x	x	x		
Upeneichthys vlamingii (Cuvier & Valenciennes)*	x	x	x	x	x	x	x			
Parapriacanthus elongatus (McCulloch)		x		x						
Pempheris multiradiatus Klunzinger	x	x	x	x	x	x	x	x	x	
Girella elevata Macleay		x	x			x	x			
Girella tricuspidata (Quoy & Gaimard)		x	x	x	x		x			
Melambaphes zebra (Richardson)	x	x	x	x	x	x				
Scorpis aequipinnis Richardson	x	x	x	x	x	x	x	x		x
Scorpis lineolatus Kner	x	x			x	x	x			
Atypichthys strigatus (Günther)	x	x			x	x	x			
Enoplosus armatus (White)	x	x	x	x	x		x			
Pentaceropsis recurvirostris (Richardson)		x	x	x	x	x	x	x		
Chromis hypsilepis (Günther)	x									
Parma microlepis Günther	x	x	x		x	x	x	x		
Parma victoriae (Günther)	x	x	x	x	x					
Chironemus marmoratus Günther		x				x				
Dactylosargus arctidens (Richardson)*	x	x	x	x	x	x	x	x	x	x
Cheilodactylus nigripes Richardson	x	x	x	x	x			x		
Cheilodactylus spectabilis (Hutton)*	x	x	x	x	x	x	x	x	x	x
Dactylophora nigricans (Richardson)	x				x					
Nemadactylus macropterus (Bloch & Schneider)*						x	x	x	x	
Latridopsis forsteri (Castelnau)*	x	x	x	x	x	x	x	x	x	x
Latris lineata (Bloch & Schneider)*									x	x
Mendesoma allporti Johnston*							x			x
Sphyraena novaehollandiae (Günther)		x								
Dotalabrus aurantiacus (Castelnau)	x	x	x	x	x		x	x		
Suezichthys sp.						x				
Opthalmolepis cyanogramma (Cuvier & Valenciennes)	x									
Pictilabrus laticlavius (Richardson)	x	x	x	x	x	x	x	x	x	
Pseudolabrus fucicola (Richardson)*	x	x	x	x	x	x	x	x	x	x
Pseudolabrus psittaculus (Richardson)	x	x	x	x	x	x	x	x	x	x
Pseudolabrus tetricus (Richardson)	x	x	x	x	x	x	x	x	x	
Heteroscarus acroptilus (Richardson)	x	x	x	x	x					
Neoodax attenuatus (Ogilby)		x				x				
Neoodax balteatus (Cuvier & Valenciennes)*		x	x	x	x	x	x	x	x	
Neoodax beddomei (Johnston)	x	x	x	x	x	x	x			
Olisthops cyanomelas Richardson	x	x	x	x	x	x	x			
Siphonognathus argyrophanes (Richardson)		x								
Bovichthys variegatus (Quoy & Gaimard)*	x	x	x	x	x	x	x	x	x	x
Acanthaluteres spilomelanurus (Quoy & Gaimard)			x	x	x	x	x	x	x	
Brachaluteres jacksonianus (Quoy & Gaimard)		x		x			x	x		
Eubalichthys gunni (Günther)	x	x		x	x	x	x	x		
Eubalichthys mosaicus (Ramsay & Ogilby)					x					
Meuschenia australis (Donovan)*		x	x	x	x	x	x	x	x	x
Meuschenia flavolineata Hutchins		x	x							
Meuschenia freycineti (Quoy & Gaimard)	x	x	x	x	x	x	x	x		
Meuschenia hippocrepis (Quoy & Gaimard)		x		x	x					
Parika scaber (Günther)	x						x	x		
Penicipelta vittiger (Castelnau)	x	x	x	x	x	x	x	x	x	
Aracana aurita (Shaw)		x	x	x	x	x	x	x	x	x
Aracana ornata (Gray)		x	x	x	x	x				
Diodon nichthemerus (Cuvier)	x	x	x	x	x	x	x	x	x	

* Cool-temperate species.

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OBSERVATIONS ON SOME TASMANIAN FISHES: PART XXX

by E.O.G. Scott
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(with five tables, three text-figures and three plates)

ABSTRACT

SCOTT, E.O.G., 1984 (31 viii): Observations on some Tasmanian fishes: Part XXX. *Pap. Proc. R. Soc. Tasm.*, 118: 187-222, plates 1-3. ISSN 0080-4703. Queen Victoria Museum and Art Gallery, Launceston, Tasmania.

ANGUILLIDAE. *Anguilla australis* Richardson, 1841: a xanthic example is reported. TRACHIPTERIDAE. (a) *Trachipterus arawatae* Clarke, 1881: two large dealfish catalogued as *T. jacksonensis* (Ramsay, 1881) are described and figured and their taxonomic status is considered, with special reference to differential growth in *T. arawatae* and in the present material, it being concluded Ramsay's species is a senior synonym of Clarke's; (b) *Zu cristatus* (Bonelli, 1820): a Tasmanian specimen previously referred provisionally to this species is here definitively ascribed to it and is made the subject of some additional observations. BOVICHTHYIDAE. *Bovichthus variegatus* Richardson, 1846: several good series from Greens Beach, northern Tasmania, allow the study of growth and form in a geographically homogeneous population. ATTENNARIIDAE. *Kuiterichthys furcipilis* (Cuvier, 1817): observations are made on this species, recently added to the Tasmanian list.

INTRODUCTION

This paper follows the general plan of others in the series. Linear dimensions are given throughout in millimetres or as thousandths of standard length. The symbols *Ls*, *Lt*, *TLs* and *TLt* denote standard length, total length, thousandths of standard length and thousandths of total length, respectively. Registration numbers are those of the Queen Victoria Museum and Art Gallery. Certain other conventions are noted in earlier contributions.

FAMILY ANGUILLIDAE

Genus *Anguilla* Shaw, 1803

Anguilla Shaw, 1803, p.15. Type-species, *Muræna anguilla* Linné.

Anguilla australis Richardson, 1841

Anguilla australis Richardson, 1841, p.22. Type locality: Port Arthur, Tasmania (Lemprière).
Anguilla australis occidentalis Schmidt, 1928a, p.388, and 1928b, pp.181,198,203, figs 2-9.

Material

A xanthic example, *Lt* 582 mm, caught by Mark Purton in the Elizabeth River, 1 km north of Campbell Town.

Xanthic fish

Xanthochroism in fishes is rare. Whitley (1964, p.22) noted the presence in the Australian Museum, Sydney of xanthic specimens of *Kyphosus sydneyanus* (Günther, 1886), cited under genus *Segutilum* Whitley, 1931, and *Girella tricuspidata* (Quoy & Gaimard, 1824): an example of the latter species caught at Stanley, northwestern Tasmania, in which the whole fish apart from the eye was bright canary yellow has been noted (Scott, E. 1980,

p.112). Of five references to the literature cited by Whitley — Kershaw (1904), Scott (1942), Whitley (1952), Anon. (1956), Haysom (1960) — the first, second and fourth relate to eels. A xanthic eagle ray, *Myliobatis australis* Macleay, 1881, has been reported from New South Wales (Whitley 1940, p.226). A second Tasmanian anguillid, from the South Esk at Longford, multicolored in yellow, brown, grey and white, was reported and figured by Scott (1953, p.147, fig.1).

Coloration of present specimen

General color virtually uniform bright canary yellow; an obscure interrupted band some 5 mm wide of very faint duskiness along lateral line from above preoperculum to about a head length behind vent and some duskiness for about a head length in hinder part of tail; eye blue; vent blackish; pectoral and dorsal wholly bright yellow; anal bright yellow with some proximal brownish patches each some 30 mm in length, last extending to tip of small caudal fin.

The specimen has a total length of 582 mm.

FAMILY TRACHIPTERIDAE

All three recent genera of Trachipteridae, *Trachipterus* Goüan, 1770, *Zu* Walters & Fitch, 1960, *Desmodema* Walters & Fitch, 1960, are known to occur in Australia; the second being first recorded in our waters by Scott (1983) (though earlier encountered in New Zealand having there been ascribed by Hamilton (1916), Phillipps (1944), McCann (1953) and Whitley (1968) to *Trachipterus* under three specific names); the third, though known from "all tropic and temperate world seas" (Fitch 1964) apparently reported from our waters only as the type specimen of the type-species *Trachipterus jacksoniensis* [=*jacksonensis*] *polystictus* Ogilby, 1897, from near Newcastle, New South Wales. A key to these genera is provided in Scott (1983, p.171).

Two large dealfish in the collection of the Queen Victoria Museum catalogued as *Trachipterus jacksonensis* (Ramsay, 1881) serve to validate the earlier suggestions (Scott 1983) of the synonymy of that species with *T. arawatae* Clarke, 1881; secondly, consideration of literature not previously available confirms the earlier provisional determination of the local example of *Zu* as *Z. cf. cristatus* (Bonelli, 1800).

Genus *Trachipterus* Goüan, 1770

For synonymy see Scott (1983, p.172).

Trachipterus arawatae Clarke, 1881

(plates 1,2; text-figure 1)

Trachipterus arawatae Clarke, 1881, p.195, unnumbered figure. Type locality: Arawata, Jacksons Bay, New Zealand.
?Cepola trachyptera Gmelin, 1788, p.1187. Type locality: Adriatic.
Regalaecus [*sic*] *jacksonensis* Ramsay, 1881, p.195, pl.20. Type locality: Manly Beach, Port Jackson, New South Wales.
Regalecus jacksonensis Macleay, 1881, p.55.
Trachypterus jacksoniensis: Ogilby, 1886, p.43: Marshall 1926, p.123 (specimen).
Trachipterus jacksoniensis: Phillipps, 1927, p.27: Munro, 1957, p.64, fig. 450 ("probably adult of" *T. arawatae*): Grant, 1978, p.134.
Trachypterus jacksonensis: Stead, 1906, p.217, and 1913, p.492 (photographs of specimen exhibited).
Trachipterus jacksonensis: Hamilton, 1916, p.372, fig. 1 (Waikanae specimen only): McCulloch, 1921, p.25, pl.11, fig.126a, and 1927, (*in*: Whitley, 1927, p.296, pl.25, fig.2), and 1929, p.138: McCulloch & Whitley, 1925, p.170: Marshall, 1964, p.135, pl.29, fig.135, and 1966, p.435, pl.29, fig.135.
Trachipterus arawatae: Scott, 1983, p.172, pls 1-3, figs 1-6 (table of Australasian synonymy).

Taxonomy of Australian trachipterids

Scott (1983) attempted to clarify the confusion in which the systematics of the Australasian trachipterids has been involved. Three names have been proposed for material with an Australian or New Zealand type locality: (a) *Trachipterus arawatae* Clarke, 1881, (b) *T. jacksonensis* (Ramsay, 1881), (c) *T. jacksonensis* ["*jacksoniensis*"] *polystictus* Ogilby, 1898. The first of these has frequently been incorrectly relegated in recent years to the genus *Desmodema* Walters & Fitch, 1960 (of which (c) is the type-species), while earlier texts listed the common local dealfish under one or other of a number of extralimital species, e.g. *Trachipterus trachyptera* (Gmelin, 1788), *T. arcticus* (Brünnich, 1788), *T. taenia* (Schneider, 1801), *T. altivelis* Kner, 1819 (the name under which Johnston (1883a) listed the first Tasmanian record of a trachipterid), *T. spinolae* Valenciennes, 1835, *T. falx* Valenciennes, 1835, *T. iris* Walbaum, 1838, *T. ishikawae* Jordan & Snyder, 1901. The history and status of Ramsay's species (b) are discussed below. Though represented locally only by the type-specimen, Ogilby's taxon (c) has held its place (with some variation in spelling) in Australian texts, in general enjoying its original status, though McCulloch (1921) suggested Ogilby's specimen ~~was a young~~ example of Ramsay's fish, (b), formally adopting the synonymy in the Check-list (1929): since the establishment of *Desmodema* it has correctly been referred to that genus. Attention may be called to the fact that in nominating it as the type-species of their genus Walters & Fitch (1960) cited its date as 1897, as also did Fitch (1964): the date of publication was 8 February 1898.

Material

Series A: two specimens in the collection of the Queen Victoria Museum and Art Gallery, Launceston, both registered as *Trachipterus jacksonensis*, (a) Circular Head, northwestern Tasmania, collected 4 November 1942 (H.J. Burgess), Q.V.M. Reg. No. 1943/3, length without caudal 1 060 mm, total length 1 190 mm, (b) mouth of Inglis River, northwestern Tasmania, collected November 1943 (R. Inglis), Q.V.M. Reg. No. 1943/122, length without caudal, mouth protracted 1 260 mm, mouth not protracted ca. 1 230 mm, length of caudal 112 mm; the larger individual is partly severed at two points but remains intact; the bones of the head are damaged.

Series B: eight Tasmanian examples (of which seven only are used in statistics) of *Trachipterus arawatae* in the Museum's collection, specified in Scott (1983, p.172), lengths to caudal base, mm, 100, 212, *ca* 296, 444, 508, 555, 560, Q.V.M. Reg. Nos 1971/5/3, 1973/5/3, 1957/5/4, 1945.13, 1942.1, 1973/5/4, 1969/5/4. The eighth individual (damaged) has length to caudal base *ca* 630 mm.

Meristic characters

Specimen (a) is noted first throughout: an entry in parentheses if preceded by R is from Ramsay (1881), S Stead (1913), H Hamilton (1916), Ma Marshall (1926), Mc McCulloch (*in*: Whitley 1927), Mu Munro (1957; synoptic). First dorsal 5 (R 5-7, H 6, Mc 5, Mu 5-7), no data for (b). Second dorsal to vent 72 (R 75) behind vent *ca* 80, in (b) no satisfactory count possible near origin, from level of operculum to vent 58, anterior to this perhaps a dozen, giving estimated total before vent *ca* 70, behind vent 80 (total H 174, Ma 176, Mc 130+, imperfect posteriorly). Pectoral, 12 on both sides, 11 on both sides (R 14, H 11, Ma 14, Mc 14). Caudal 5, 6 (specimen (b) with two strong processes directed backward; pl.2, fig.B). Branchiostegals 6 (H 6, Mc 6). Gill arches 4, slit behind 4th (Mc ditto), 5 short broad rakers on hind wall of last slit. Gill rakers on anterior arch 14, 12 (Mc 12). Lateral line to vent 65, *ca* 62 (R "about seventy"), behind vent 38, 40.

Here and elsewhere linear dimensions are given unless otherwise indicated as thousandths of length to caudal base, treated as standard length, *Ls*. Entries for (b) accept as standard length that as estimated with the mouth parts retracted (1 230 mm). Lengths of examples noted in the literature: R total length, end of tail wanting, 1 422 mm, restored about 1 830 mm, S2 195 mm plus an estimated 250 mm = *ca* 2 445 mm, H approximately 1 830 mm, Ma 1 925 mm (snout protracted), Mc 1 929 mm, incomplete, Mu synoptic, 2 134 mm. Head 108, *ca* 114 (R 111, H 111, Mc somewhat <130, Mu 132). Snout 38, *ca* 39. Eye horizontal diameter 41, 35, vertical diameter 36, 31 (eye: R 32, S 25, H 34). Interorbital 11 *ca* 10 (Mc "about 2/3 eye"). Length to pectoral 108, 113. Length to ventral 127, 133. Length to vent 462, 469 (R *ca* 493, Mc round about 500). Depth at front of eye 77, —, at back of

eye 85, —, at operculum 127, 130 (S at adjacent ventral insertion 106), at vent 123, 138, maximum 142, 154 (Ma 114, Mc 111, Mu 137), width at same points 11,—;11,—;16,14;11,5; maximum 16, 4 (S 23). Length of caudal 123, 91; of ventral 6,6; 8,7; of pectoral, left 34, 21, right 31, 32 (H 29, Ma 45, Mc 60); pectoral base 9.4, 9.3. Length of longest dorsal ray 77, 85 (R 32, H "about 1/3 the height of the body", Ma 46, Mc (100th ray) 52). Length of longest pterygiophore 51, 51. Maxillary plate length 40, 39, width 22, 23 (Mc "more than half as wide as deep", Mu "twice deeper than long"). Length of premaxillary process 66, *ca* 59.

Proportions

Some proportions conventionally reported are here noted for specimens (a) and (b), followed in round brackets by some values from the literature, and in square brackets by range and mean, with standard error, of the seven well-preserved specimens of sample B. Head in *Ls* 9.2, 9.8 (R 11, H 9, Mc round about 8, Mu 7.6) [4.5-5.8, $\bar{x}$ 6.99±0.650]. Head in length to vent 4.3, 4.1 (T "four and a-quarter", Mc *ca* 3.8) [2.8-4.4, 3.74±0.205]. Length to vent in *Ls* 2.2, 2.1 (R 2.6, H 2, Mc *ca* 2) [1.4-2.1, 1.81±0.106]. Greatest depth in *Ls* 7.6, 6.5 (Ma 8.8, Mc 7.7, Mu 7.6) [3.9-6.3, 4.78±0.524]. Depth at vent in *Ls* 8.6, 8.9 (S 9.4), [5.6-8.5, 7.68±0.444]. Depth at vent in length to vent 4.3, 4.2 (R "four and a-half', H 4) [3.4-4.7, 3.94±0.148]. Mean depth (mean of 10 equidistant measurements) in *Ls* 12.3, 11.8 [6.2-10.7, 8.83±0.725]. Eye in head 2.6, *ca* 3.4 (R "three and a-half", H 3) [3.2-3.9, 3.58±0.095]. Snout in head 2.8, *ca* 2.9 [2.8-3.9, 3.25±0.169]. Interorbital in eye 3.7, *ca* 3.6 (Mc "interorbital width about 2/3 diameter of eye") [1.2-3.1, 1.65±0.248]. Length of longest dorsal ray in *Ls* 12.9, 11.7 (R 31, Mc (50th ray) 19.3) [5.0-11.6, 8.37±0.845].

Description

Body greatly compressed, width at eye, *TLs*, 11.3, —; at operculum 16.0, 13.8; at vent 11.3, 15.4, or 7.4, —; 7.9, 9.4; 10.8, 8.9 in depth there. Pennon shaped, attenuate, more so than as depicted by Ramsay (1881, pl.20) or McCulloch (*in*: Whitley, 1927, pl.25, fig.2), both their specimens, however, being imperfect posteriorly and lacking the caudal fin; markedly more slender than the type specimen of *T. arawatae* and than Victorian examples figured by M'Coy (1886, pl.122), as *T. taenia*. Dorsal profile arched, rising slightly from nape to its highest point at about 35% of standard length, thence curving down regularly. Ventral profile approaching straight to within about one-third head length of vent, thereafter continuing backward still approximately straight, but proceeding upward at an angle of 7°-8° to previous direction. Entire body covered with small dermal tubercles, subcircular or slightly longitudinally elliptical, somewhat elevated laterally but with most of surface flattish; some variation in size, with modal diameter about 1 mm, interspaces from less than diameter (modally) up to twice diameter, shortly behind head about 90/cm ; two rows of slightly enlarged tubercles along each pterygiophore; in (b) a band of 2-3 larger, bordering the pectoral girdle behind; a conspicuous band, 5-7 wide but not in regular rows along whole ventral border, greatest width about 7 *TLs*, womewhat mounded or pointed, some with distinct median projection, members of this band distinctly knobbly to touch, in contrast to significantly smooth feel of general body surface; along lateral line coalescing to form more or less distinct small plates each with a central spine, similar in all respects to those of sample B. These dermal tubercles are referred to in Ramsay's original account as osseous scutes; attention being called to their differentiation as "oblique bands from the interspaces of the rays" and along the abdominal line.

Lateral line begins at the top of the shoulder girdle level with upper border of pupil; after a brief upward convexity proceeding in (a) almost straight to its end, in (b) bending down somewhat in last one-quarter of tail, the variation in its distance from the dorsal profile, specified below, being much more a function of the curvature of the body outline than of its own curvature: in both individuals it reaches, or virtually reaches, the ventral profile some little distance in advance of caudal origin. Measurements of distance from dorsal profile have been made at 10 equidistant intervals, the mean values for (a) and (b) being well represented by the following 3° polynomial, in which N is serial number of measurement: $H = 27.71+35.863N-7.7808N^2+0.39229N^3$; R 0.983; predicted (measured) distances, *TLs*, 56.2 (58.0), 71.4 (69.0) 75.9 (75.2), 71.8 (73.5), 61.5 (63.8), 47.5 (49.1), 32.0 (31.9), 17.5 (16.3), 6.2 (8.3), 0.6 (2.0). Plates decreasing in size caudad, length near origin of line about 3 mm, at vent 12, near termination 19, here as

A

B

PLATE 1 - *Trachipterus arawatae* Clarke, 1881. An example from Circular Head, northwestern Tasmania, length without caudal 1 060 mm (Q.V.M. Reg. No. 1943/3) catalogued as *T. jacksonensis* (Ramsay, 1881). A: General lateral view × about 0.1. B: Head and anterior part of trunk; × about 0.33. Photo: R.H. Green.

long as the lengthened vertebra; each plate with a single spine, minute anteriorly, progressively increasing in length; on last 8-12 plates about 1.5 mm long, recurved, in a conspicuous series along ventral border – an average of about one pair of lateral line plates per postanal vertebra is diagnostic of *Trachipterus*.

A fairly detailed account of the head, accompanied by an illustration, based on sample B, has been given in Scott (1983). The specifications given there are in general applicable to the two large individuals of sample A; however some significant points may be noted. Figures by Ramsay and McCulloch show the superior profile slightly convex, a still lesser degree of convexity being presented by our specimens; general overall slope here noticeably greater in McCulloch's plate (about 50° as against about 40°), somewhat greater still in the Tasmanian fish. Premaxillary process terminating above middle of eye,

distance from eye here 0.3 length of process. Maxillary plate, the proportions of which are generically diagnostic, to below 0.1 eye; its length 1.9, 1.7 its width (M "more than half as wide as deep") [B, 1.5-2.0, $\bar{x}$ 1.70±1.003], or 2.7, 2.9 in head (estimated from figure R 2.9, M 2.6) [2.4-3.1, 2.71±0.0890]; shape poorly depicted by R, well by M, who correctly indicates the vertically straight segment of the upper part of the anterior border and the small concavity near the middle of the posterior border (this region having applied to it a whitish fleshy or adipose lobe). Distance of eye from dorsal profile four-fifths that from ventral. Nostril a minute vertically elliptical pore, its height somewhat less than 1 mm; border slightly elevated; distance from eye equal to that from profile directly above it, twice that from profile directly in advance of it.

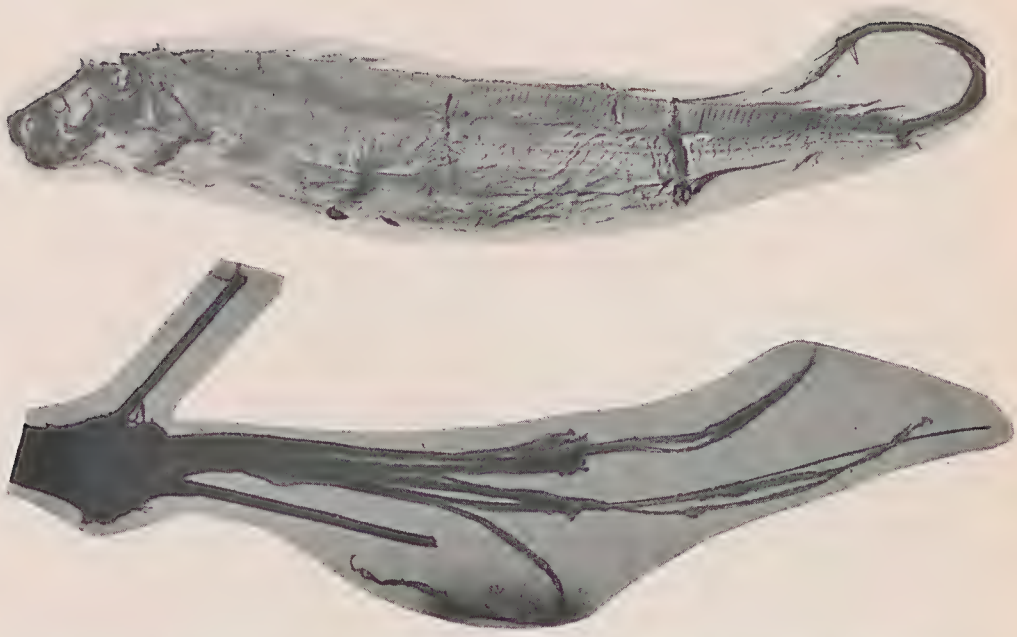
While presenting an essentially similar pattern for the opercular complex, the illustrations of Ramsay and McCulloch show some variation between them in the shapes of the bones, both representations also departing somewhat from our material. In this the preoperculum is more strongly curved, with (contrast Mc) its greatest width near the middle of its length, the length of the chord of the arc of the anterior border about one-eighth of its own length. Damage to the head makes a precise assessment of the operculum difficult; it appears to be more extensive than figured, extending back in a wide lobate membranous flap. The preoperculum, which as noted by McCulloch is movable on the exposed processes of the quadrate and hyomandibular, is the most rigid of the bones, though having a smooth membranous border. The truncate ends of the subopercular and mandible meet beneath the tip of the preoperculum.

Gill rakers on anterior arch 14, 12 (Mc 12) [4-5, modally 4 + 9-10, modally 9]; uppermost very small, largest at middle of row 4.5 mm, distance between tips 2-3 times basal diameter; tapering, acute or obtuse, most with 4-5 spines, some with fewer, but up to 9, best developed on lower border of distal half. As preserved, teeth on premaxillae in (a) 2 on one side, 1 on other, small, in (b) 5 on left, 3 on right, first, largest 2 mm long, one and a half size of last, not recurved, pointing down and back. In (a) on mandible two large recurved on each side of symphysis, pointing back and down; on vomer 2, smaller than in mandible; on each palatine 1, small: in (b) recognized only in premaxillae. (R records 4 on either side of lower jaw and 5 on either side of upper jaw, no others mentioned: Mc notes on premaxilla a single irregular row, cardiform, on mandible 2 short rows on either side of symphysis, on vomer 3 in a row, on each palatine 1 or 2) [see details for sample B in Scott (1983, p.182) and generic diagnosis of *Trachipterus* by Palmer (1961, p.339) "Recurved pointed teeth in both jaws, 6 to 12 in the upper, 6 to 10 in the lower. Vomer with 1 to 2 median teeth. Palatine teeth, if present, feeble."]

As in sample B and apparently regularly in *Trachipterus* and *Zu* vent is on midventral line — contrast *Desmodema polysticta* in which (Walters & Fitch 1960, p.446) it is often on the right or left side — small horizontally elliptical opening with some peripheral aggregation of dermal tubercles, in anterior half of fish without caudal, at 452 469 *TLs* behind snout tip (R, tail imperfect, calculated 795) [414-620 (i.e. in front or hind half), $\bar{x}$ 547.6±27.92].

The first dorsal is recognizable only in (a), the whole area being badly damaged in (b). Vestiges of 5 rays are recognizable (R 5-7, Mc 5) [5-7, ?8], 3 imperfect measuring 4.8, 6.6, 7.6 *TLs*; base 4.8. Second dorsal with in (a) 72 rays to vent, *ca* 80 behind it, in (b) estimated 70+80 (R 75 to vent) [in 5 specimens of sample B in which satisfactory counts can be made 171, 173, 174, 178, 178]. Rays smooth, slender, finely pointed, often filamentous distally. Length of longest ray 77, 85, ray above vent 66, *ca* 65. Fin traceable to penultimate vertebra.

In his description of his *Regalaecus jacksoniensis* Ramsay states, "The membrane between the dorsal rays is not attached to the back, but only at the base of each ray", and small void lunules are evident in the plate. No mention of the imperfect attachment of the membrane was made in the excellent description of the Port Jackson specimen by McCulloch, nor is it shown in his plate; it has apparently escaped the notice of other Australian authors. It was, however, picked up by Hamilton in New Zealand, whose description of an example of *T. jacksonensis* (1916, p.372, fig.1) from Waikanae, near Wellington (noted as being only the second recorded occurrence of this species in the Australasian



B

PLATE 2 - *Trachipterus arawatae* Clarke, 1881. An example from the mouth of the Inglis River, northwestern Tasmania, length without caudal *ca* 1 230 mm (Q.V.M. Reg. No. 1943/122) catalogued as *T. jacksonensis* (Ramsay, 1881). A: General lateral view, × about 0.1. B: Caudal fin, showing globose base, long flexible rays and two rigid basal processes.. Photos: R.H. Green.

region) was evidently compiled with Ramsay's account before him. He observed it also in four other fish identified as *Trachipterus trachypterus* (Gmelin) (= *T. arawatae* Clarke), but made no mention of it in a brief account of a juvenile from Nelson, identified by him as *T. jacksonensis*, but referable to the genus *Zu*. Further, in his observations on the Waikanae fish Hamilton noted the membrane is double. These conditions obtain also in our material in both samples A and B; the two sheets of membrane, however, being closely apposed and separable only with difficulty.

It is of interest to note this peculiarity of attachment of the dorsal membrane extends beyond the Trachipteridae, occurring also in the Regalecidae, being quite obvious in the example of *Regalecus glesne* Ascanius, 1778 the subject of some observations (as *R. pacificus* Haast, 1875) by Scott (1982, p.189, pls 2-4).

Caudal 5, 6 [6, 8]; length to fin 1 060, 1 230 mm; length of fin 460, 469 *TLs* [for 5 specimens of B 47-480, $\bar{x}$ 240.2±75.6]. The last normal vertebra compressed, elongate, its length more than twice its width, more than one-third eye (preceded for some distance by similar vertebrae, gradually decreasing in size forward, each with a single median spine) is followed by a wider globose segment, its transverse diameter about half its longitudinal. This specialized segment, presumably housing the hypurals, is not wholly symmetrical; here and in sample B, where it may be more or less fan-shaped, it presents a curious suggestion of having been subject to some distortion. From about the middle one-third of its posterior border arise the 5, 6 caudal rays, closely set, slender, tending to become filamentous distally, delicately spinose on each lateral surface, their general direction collinear with the vertebral column. In (b) there arise from this segment two rigid slender subcylindrical acute processes, each at an angle of about 45° to the body axis, the upper, 20 in length, arising from near the junction of the terminal segment with the last vertebra,

the lower, 30 in length, from the hind border shortly below the lowest ray (plate 2, fig. B). One or two much shorter rigid processes in this region have been found in sample B (Scott 1983, p.184). Pectoral 12 (both fins), 11 (both fins) (R, Mc, 14) [11(1), 12(3), 13(3)], inserted immediately behind pectoral girdle, slightly closer to ventral profile immediately below it than to level of lower margin of orbit; base short, about one-fourth eye (R, Mc, figures, approximately half), almost horizontal; rays carried somewhat backwardly obliquely (as in Mc's figure, not almost horizontally as in R's figure), first ray very small, length increasing to fourth, thereafter decreasing, last noticeably shorter than penultimate (R, "the first very small and short", Mc, outer two very short, median longest); bases wider, less closely spaced after 3rd. Lengths of left and right fins in (a) 34, 21, in (b) 31, 32 — the marked difference in (a) being perhaps indicative of instability of growth concomitant with the rapid decrease in relative magnitude the fins undergo with increase in overall size of fish. In the left fin of (a) the rays 2-9 (i.e. those other than the small rays at the margins) are significantly specified by the following equation, in which L is length of ray, N^1 the inverse serial number of ray, counting (Scott 1974, p.248) as the first the uppermost ray: Log L = $0.0305N^1+1.2075$; t 22.668***; predicted (measured) lengths, *TLs*, 31.3 (31.1), 28.3 (28.8), 26.4 (25.5), 24.6 (24.1), 22.9 (22.6), 21.4 (21.7), 19.9 (19.8), 18.6 (18.9).

In the type specimen of *T. arawatae*, 64 mm in length to caudal base, the ventral forms an impressive fan 3.4 times head (Scott 1983, p.183, in error, "in head"), and while it is decidedly smaller in sample B, ranging from 0.8 to 1.13, $\bar{x}$ 1.03±0.098 in head, or 6.7 1.12 in *Ls*, it there remains much longer than the pectoral. In the large dealfish identified as *T. jacksonensis* the ventrals are represented by "a short, slender tubercle on either side of a triangular space opposite the posterior base of the pectoral" (Ramsay), "is worn off, but shows the insertion of two spines in a triangular space opposite the base of the pectoral" (Hamilton), "is either entirely absent or so rudimentary as to be inconsequential" (Marshall), or appear as "two tubercles in pits in the skin just behind the vertical of the posterior angle of the pectoral base" (McCulloch); "reduced to small tubercle" (Munro). In our sample A they have undergone comparable degradation, being present in the form of a dark brown flap, pennon-shaped in (a), falcate in (b), apparently of a fleshy nature, without obvious indication of rays; length 6.6, 8.7 *TLs*, or 0.2, 0.3 length of pectoral; inserted behind head by 18.9, 18.5 *TLs* or 0.17, 0.16 head length; set very closely together, >2 mm apart, in the narrow ventral band of the tubercles.

The radialia, pterygiophores, of the second dorsal fin present a conspicuous palisade along the upper half of the fish. Means of lengths of (a) and (b) for 10 measurements taken at equal intervals along general anteroposterior axis of fish range from 2.6 (last decile) to 55.7 (3rd), with overal mean 29.04±6.716 *TLs*; compare in the generally deeper fish of sample B a maximum height of 45.0-80.0. Their height, being a compound fraction of the dorsal profile and the course of the lateral line (more or less conformable with that of the vertebral column), yields a complex curve when plotted against length of fish, reaching a peak at the 3rd decile in specimen (a), the 4th in (b), thereafter being sigmoid. For (a) 10 heights (H), taken at 10 equal intervals (serial number N) are tolerably satisfactorily specified by a 3° polynomial: $H = -18.11-50.544N-10.1272N^2+0.53032N^3$; R 0.889; predicted (measured) heights, *TLs*, 22.8(22.6), 46.7(45.3), 56.7(59.4), 56.0 (58.0), 47.7(44.3), 35.6(35.4), 21.4(18.9), 9.3(10.8) 3.1(6.6), 4.9(2.8).

Coloration

Ground color in (a) purplish slate, in (b) becoming slaty below lateral line. Position and form of pterygiophores marked by pale brownish bars, their interspace in (a) greyish in (b) deep cream; at upper end of each a much darker vertical stroke, some 5 *TLs* long, its upper extremity expanded, its lower pointed. A well-marked band of pale greyish above whole length of lateral line, its width above vent about 20, somewhat less behind head, decreasing regularly caudad from vent, width halfway to caudal 10; from vent backward paralleled by a lesser band below lateral line. Band of tubercles along ventral border lighter than body immediately above it. The myomeres are marked out by conspicuous dark lines, with lighter interspaces once to twice their width, in much of the body, with one full chevron evident above the lateral line and the upper half of a forwardly directed chevron below it, lower part of flank unmarked. Lateral line ranging from orange to brick red, darker round spine base. Head in general dark brown, the plates somewhat shiny, more

or less uniform. Whole frontal aspect a very dark brown, in parts almost black, bar, extending beyond tips of premaxillary processes to first dorsal origin. Dorsal and pectoral rays bright somewhat olivaceous brown, caudal rays darker; fin membranes translucent.

Ontogenetic change

Few if any families are characterized by more extensive and striking changes during ontogeny than the Trachipteridae. Four successive stages of development may here be conveniently, if somewhat arbitrarily, recognized: (a) the larval stage, (b) the immediately postlarval stage, (c) the period during which the length of the fish without caudal fin ranges from round about 100 mm to 500-600 mm, and (d) the period of subsequent growth. The complex history of phases (a) and (b) has been the subject of investigation for upwards of a century, associated with it being the classic researches of Emery (1879a,b), followed by contributions from Smitt (1893), Ehrenbaum (1905), Lo Bianco (1908), Jacino (1909), Sanzo (1918), Hubbs (1926), Sparta (1932), Walters & Fitch (1960), Palmer (1961), Fitch (1964) and numerous other authors. The most obvious developmental features subsequent to stage (c), resulting in marked differences in the general appearance of the fish, include decrease in relative size of the nuchal crest, in that of the pectoral fin and (as reported by Ramsay) in the relative height of the second dorsal, the reduction of the ventrals to vestiges, a modification of the caudal, involving the virtual disappearance of the lower lobe usually accompanied by an alteration in alignment of the upper lobe from oblique to main anteroposterior axis to collinear with it. Attention is directed in the present paper to stages (c) and (d), in particular to an inquiry as to which, if any, quantitative specifications found in, and apparently first reported in, an earlier contribution (1983) to characterize stage (c) as represented by sample B (*Ls* 100-560 mm) may legitimately be extrapolated to cover the conditions encountered in stage (d) as represented by the present examples of *Ls* 1 060, 1 230 mm, catalogued as *T. jacksonensis* (with further reference, where applicable, to the accounts under Ramsay's name by Stead, Marshall and McCulloch).

Differential growth

It was found earlier that in sample B, with *Ls* range 100-560 mm, the relative lengths of a number of features are correlated (in all major items, other than length of tail, negatively) with overall size; graphs of growth of head, trunk, tail there being shown (Scott 1983, fig.1). The differences in magnitude are considerable, the mean value for the three specimens of *Ls* 508-560 mm being for the head only 53%, for the trunk 93%, for the tail 135% that of the smallest individual (*Ls* 100). While trunk length exhibits consistent decrease, the graph resulting when it is plotted against standard length is neither significantly linear with arithmetic values nor significantly linear as a rectified logarithmic formulation. Accordingly the equation for length of head is here complemented with that for tail.

Table 1 sets out equations of regression of logarithmic lengths, *TLs*, of selected features on standard length, mm, in sample B, recording mean measured and estimated values of the three large individuals of B (*Ls* 505, 555, 560 mm), together with extrapolations to the overall lengths of the two large specimens of sample A and to those of the still larger dealfish identified as *T. jacksonensis* by Ramsay (1881), Stead (1913), Marshall (1926) and McCulloch (*in*: Whitley 1927). For all features considered, linear formulations give negative measures of length for all four large specimens in the literature (and in most instances also for specimens of sample A): accordingly only logarithmic equations are given in the table.

With conspecificity of samples A and B assumed, three models suggest themselves for cases in which the relative magnitude of the relevant morphological feature is less in A than in the small individuals of B. In the first of such models, which may be designated that of arrested change (decrease), the values for A are subequal to those for the larger individuals of B; in the second, the model of steady rate change (decrease), the values for A are subequal to those that would result from extrapolation from a regression equation for B to the standard lengths of A; in the third, the model of variable rate of change (in the form of an increase), the values for A are noticeably less than those yielded by such extrapolation.

TABLE 1

Trachipterus arawatae Clarke, 1881

Differential growth. Equation of regression of logarithmic magnitudes, as thousandths of standard length, of ten morphological features on standard length, *Ls*, mm, in seven individuals, *Ls* 100-560 mm (sample B), with mean value for three larger specimens; and with extrapolations for two specimens, *Ls* 1 030, 1 230 mm, catalogued as *T. jacksonensis* (Ramsay, 1881) (sample A), also for Ramsay's type specimen and for three large fish identified as Ramsay's species by Stead (1913), Marshall (1926), McCulloch (*in*: Whitley, 1927); M = measured, E = estimated.

Feature	Log X=m*Ls*+c		t	SAMPLE B		SAMPLE A				Extrapolations from published accounts (estimates from text or figure)			
						spec.(a)		spec.(b)					
	$m \times 10^4$	c		M	E	M	E	M	E	Ramsay	McCulloch	Marshall	Stead
Length of head	5.723	2.3791	8.044***	116	118	109	59	114	47	22	19	18	10
Length of tail	4.190	2.4815	20.509***	514	511	538	843	531	993	1 770	1 941	2 048	3.106
Maximum depth	4.716	2.4615	4.626**	167	161	150	92	155	76	40(125)	36(13)	34(114)	20
Depth at vent	3.200	2.2639	10.276***	128	123	123	84	138	74	48	44	43	30
Mean depth	6.707	2.3366	12.421***	95	94	82	48	87	38	18	16	15	8
Length to pectoral origin	6.044	2.3799	8.100***	109	113	108	55	113	43	19	16	15	8
Length to ventral origin	5.646	2.4373	8.198***	136	136	127	69	132	55	25	22	21	11
Length of longest dorsal ray	5.890	2.3295	11.900***	103	103	77	51	85	40	18	16	15	8
Length of pectoral	8.151	2.0710	10.931***	42	46	34	16	21	12	4(63)	3(60)	3(45)	1
Length of ventral	1.009	2.5774	4.980**	113	108	7	32	9	22	5	4	4	1

Figures 1A-1J show for all individuals of A and B (for length of pectoral, only six measurements, both fins imperfect in example of *Ls* 100 mm) the value for each of the ten morphological features included in table 1, with the best straight line added. The very small magnitudes resultant upon extrapolation to the standard lengths of the large examples noted in the literature afford a striking demonstration of the proposition that the progressive relative variations (decreases) found in the smaller specimens cease to operate at a standard length of about 600 mm.

It is found the first model, predicating the cessation of differential growth at the upper limit of overall size in B and thus being indicative of the virtual achievement there of the adult conformation is valid for the following features: lengths of head and of tail, depth (maximum, at vent, mean), lengths to origins of pectoral and ventral fins, length of longest dorsal ray, all dimensions being logarithmic values. The situation regarding the lengths of the paired fins is a different one, the graph for length of pectoral (fig. 1I) being best interpreted as a continuation of relative decrease at a decreased rate, while that for length of ventral (fig. 1J) is clearly indicative of an accelerated rate of decrease. While it would clearly be more satisfactory to have data from a more extensive sample than the present, the material here examined appears to provide good evidence that in respect of general body shape and proportions a close approximation to the adult state is reached at a standard length of round about 600 mm, with the paired fins, particularly the ventral, and the nuchal pennant continuing to suffer relative diminution with increase of overall size of fish. In view of the exponential nature of the growth process the acceptable formulations are predictably found to be logarithmic.

Status of Ramsay's species

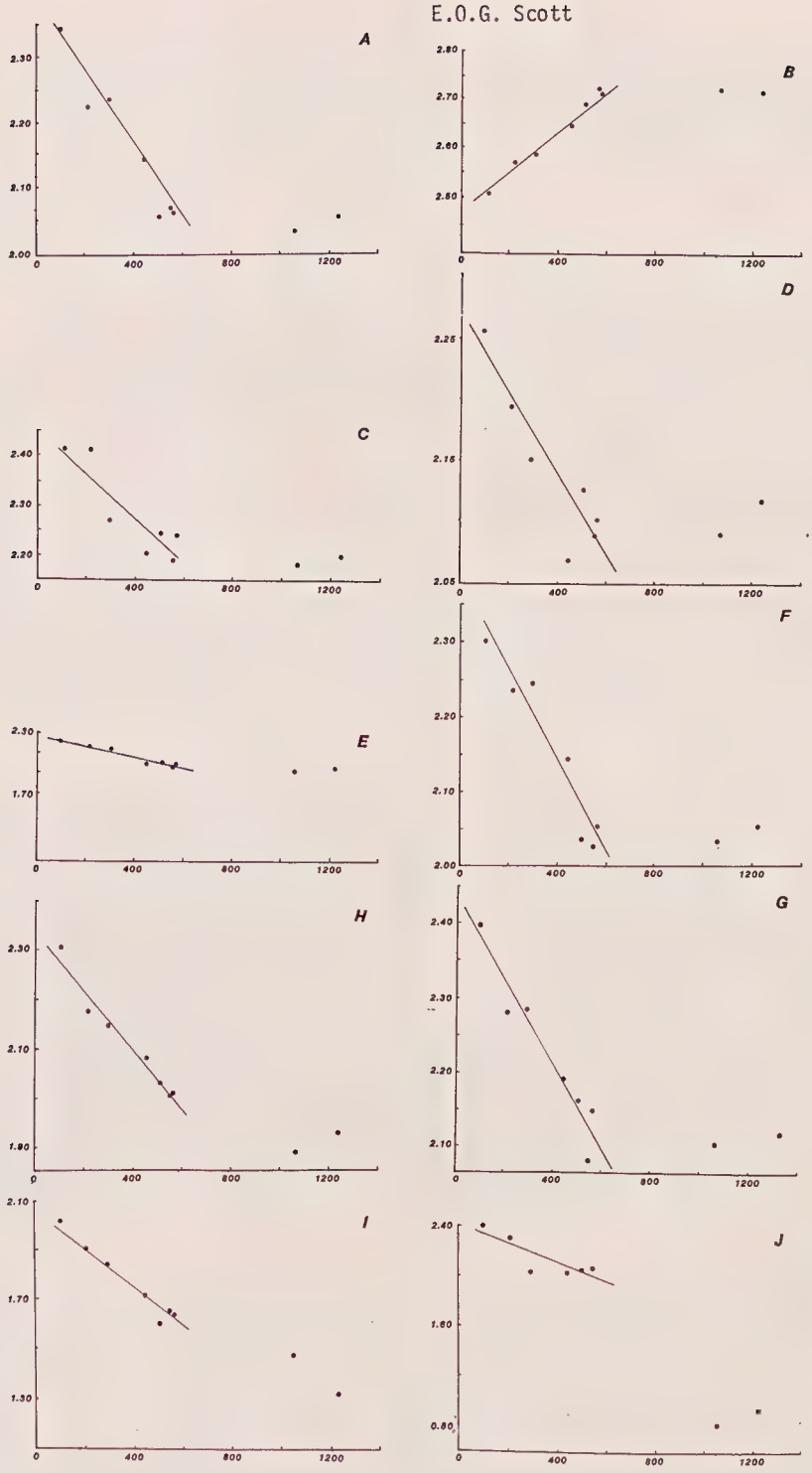
As is evident from the table of synonymy provided above, *Regalaecus jacksoniensis* Ramsay, 1881 — by all authors after Macleay (1881), who emended the generic spelling to the conventional *Regalecus*, referred to *Trachipterus* — has with few exceptions been accepted by Australasian writers as a valid species [with in some instances some unfortunate taxonomic confusion, e.g. by Hamilton (1916) who, while correctly ascribing his Waikanae fish (fig. 1) to *T. jacksonensis*, also applied this name provisionally to a fish from Nelson (fig. 2) in fact a species of *Zu*, a similar course to this latter being definitively adopted by Phillipps (1944)], a procedure continuing to prevail till quite recently (Grant 1978). However, as early as 1898 in his paper on *T. jacksoniensis* [= *jacksonensis*] *polystictus*, since proposed (Walters & Fitch 1960) as the type-species of *Desmodema*, in discussing the general taxonomy of Australian trachipterids, Ogilby stated "I think, however, that the individual described by Ramsay from Manly Beach is the adult form of those so beautifully figured by M'Coy from Portland [M'Coy (1886) identified as *T. taenia* = *T. arawatae*] nor [*sic* = and] that Hutton's and Johnston's fishes [Hutton 1873, 1876, Johnston 1883a, identified as *T. altivelis* = *T. arawatae*] must be placed in the same category with the latter, the dark spots on most of these examples being merely indicative of immaturity. Ogilby's remarks were considered by Hamilton (1916) who, however, on the basis of the character of fin rays, tended to favour a contrary view. Some six decades after Ogilby's paper his suggestion was again advanced by Munro, who in his Handbook, while giving *T. jacksonensis* formal listing (species 450), basing his account largely on Ramsay's and reproducing his figure, observed "Probably adult of species preceding" (449, *T. arawatae*). The examination now possible of local dealfishes with standard lengths in excess of a metre supports synonymy of Ramsay's species with Clarke's (Scott 1983).

The main points that have been held to distinguish *T. jacksonensis* from *T. arawatae* are: (a) larger size; (b) "having the dorsal ray in the forehead reduced into weak, short hair-like spines" [rays] (Ramsay); (c) "front profile of head convex" [*T. arawatae* "concave"] (Munro); (d) ventral reduced to "a short, slender tubercle" (Ramsay), "either entirely absent or so reduced as to be inconsequential" (Marshall), tubercle in pit (McCulloch); (e) decrease in height of main dorsal fin; (f) reduction in length of pectoral; (g) absence of "the granulations on the fin rays, and also the spiny tubercles at the base of the spines" (Hamilton); (h) absence of pronounced color markings, in particular of large dark spots, characteristically four, in *T. arawatae* (found also in northern hemisphere species of *Trachipterus* — a variation in pattern of five spots being a prime diagnostic character of *Trachypterus pentastigma* Norman, 1922 from Japan).

With regard to (a) overall size, Ramsay's species as represented by the holotype and specimens ascribed to it by Stead, Hamilton, Marshall, McCulloch ranges in reported length (some individuals imperfect posteriorly) from 1 829 to 2 445 mm, averaging in excess of 2 m; Munro's synoptic specification "7 feet" (2.13 m). The obvious question that presents itself is this: if Ramsay's species represents a taxon other than *T. arawatae*, what and where to be found is the young stage? The distinction noted in (c) is invalid, the slope of the front of the head depending on whether or no the mouth parts of the specimen are protruded (Scott 1983, p.179). It is to be noted in regard to (e), height of second dorsal, that while in those large specimens for which data are available the fin suffers some diminution in attitude, this is more marked in the holotype and in Hamilton's individual than in others. This feature, (e), and features (b), (d), (f), (h), together with reduction to a vestige of the lower lobe of the caudal and often a change from an oblique to a more or less horizontal posture of the other lobe (fin missing in Ramsay's and McCulloch's specimens) are known to occur, though commonly to a lesser degree, in the course of growth of *T. arawatae* (see section, Differential growth, above), and indeed in that of various species of *Trachipterus* recognized in the northern hemisphere. In his treatment of the Waikanae specimen of *T. jacksonensis* Hamilton observed, "Unless the adult forms of this lose the granulations on the fin rays, and also the spiny tubercles at the base of the spines, there can be no identity of *T. taenia*, *T. altivelis*, or *T. polystictus* with a form like *T. jacksonensis*, which has no spinules or granulations on the spine rays. As far as at present known, no radical change takes place on the surface of the fin rays with increasing age." As his other examples of *Trachipterus*, identified as *T. trachypterus* (Gmelin), had standard lengths of round about 600, 350, 285, 270 mm (estimates from scales given with figs 3-6), and as he goes on to remark that though Hutton in his accounts of two specimens of *T. altivelis* (Hutton 1873, 1876) makes no mention of granulation of the fins he would have noted it if it were missing and hence it may be assumed granulations were present, the argument has the appearance of being a circular one. In our material it is found that in A in proceeding from the smallest example (*Ls* 100 mm) to the largest (*Ls* 560 mm) the dorsal and caudal rays show some indication of decrease of the intensity of the spinulation and of the size of its elements, the dorsal rays of the largest individual modally being smooth in the distal one-fifth or one-fourth: in both individuals of B (*Ls* 1 060, 1 230 mm) the dorsal rays are smooth, the caudal distinctly spinose.

Two structures in the type specimen of *T. arawatae* — the "little rudimentary dorsal" behind the main dorsal and the "low rudimentary anal fin" immediately anterior to the caudal origin — the presence of which was stressed by Clarke as distinguishing his species from all published accounts, though not occurring in our specimens catalogued as *T. jacksonensis*, are not relevant to the question of the status of Ramsay's species. Clarke's fish was only 64 mm in standard length, and these supposed diagnostic characters are now known simply to be those of the postlarval stage, being lost with advancing age (hence not "rudimentary" but vestigial). As Hamilton pointed out the small individual, 66 mm, figured by M'Coy (1886) as *T. taenia* shows what appears to be a vestige of an anal fin, represented only by a trace in the larger individual, *Ls* 260 mm. Palmer (1961) reported of an example of *T. arcticus* 32 mm in standard length, "Caudad to the last stained dorsal ray and continuous with it is a lobe containing a number of thin filamentous structures, which may be actinotrichia. There is also a similar structure on the ventral surface, which is not present in the adult."

FIG. 1 - *Trachipterus arawatae* Clarke, 1881: data for seven examples, standard length 100-560 mm (at left) and two examples, catalogued as *T. jacksonensis*, standard lengths 1 060, *ca* 1 230 mm (at right). Logarithmic values of ratio of parameters noted below to thousandths of standard length (vertical axis) plotted on standard length, mm (horizontal axis); illustrating continuation or cessation in the large individuals of differential growth with age exhibited by the smaller individuals. Fig. A, length of head. Fig. B, length of tail. Fig. C, maximum depth. Fig. D, depth at vent. Fig. E, mean depth. Fig. F, length to pectoral origin. Fig. G, length to ventral origin. Fig. H, length of longest dorsal ray. Fig. I, length of pectoral. Fig. J, length of ventral.


A
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2.20
2.10
2.00
0
400
800
1200
B
2.80
2.70
2.60
2.50
0
400
800
1200
C
2.40
2.30
2.20
0
400
800
1200
D
2.25
2.15
2.05
0
400
800
1200
E
2.30
1.70
0
400
800
1200
F
2.30
2.20
2.10
2.00
0
400
800
1200
H
2.30
2.10
1.90
0
400
800
1200
G
2.40
2.30
2.20
2.10
0
400
800
1200
I
2.10
1.70
1.30
0
400
800
1200
J
2.40
1.60
0.80
0
400
800
1200

FIG. 1

It is concluded there appears to be no valid reason for regarding *T. jacksonensis* as specifically distinct from *T. arawatae*, but there are good grounds for treating it as the adult of the latter. While Ramsay's and Clarke's descriptions were both published in 1881, Clarke's paper (April) has priority over Ramsay's (20 May).

Genus *Zu*

Zu Walters & Fitch, 1960, p.445. Type-species, *Trachypterus cristatus* Bonelli, 1820.

Zu cristatus

Trachypterus semiophorus Bleeker, 1868, p.279, figure. Type locality: Amboina.
Trachypterus ijimae Jordan & Snyder, 1901, p.311, pl.17, fig.9. Type locality: Bay of Tokyo, between Misaki and Bōshu.
Trachipterus jacksonensis: Hamilton, 1916, p.374, fig.2 (Nelson, New Zealand). *Nec Regalaecus* [*sic*] *jacksonensis* Ramsay, 1881.
Trachipterus semiophorus: Fitch, 1964, p.233.
Trachipterus ijima: Fitch, 1964, p.233.
Trachipterus sp., *cf. Zu cristatus* (Bonelli, 1820): Scott 1983, p.188, pls 1-3 (synonymy).
For further synonymic taxa see Scott (1983, p.188).

Synonymy

Two species call for comment. Observing *Zu* may be monotypic, Palmer (1961, p.347) remarked, "Confirmation of this fact, however, must be left for Walters *et al.* [i.e. Walters & Fitch]. It is for this reason that I have not included *T. ijimae* Jordan & Snyder 1901 from Japan or *T. semiophorus* Bleeker 1868 from Amboina in the synonymy of *Zu cristatus*." These species have since been accepted as conspecific with Bonelli's species by Fitch (1964): examination of illustrations and descriptions of them would suggest the probable validity of the attribution.

Comparison with holotype

Comparison of our specimen, *Ls* 405 mm, *Lt ca* 525 mm, with the description and figure of the holotype, *Ls* 590 mm, *Lt* 700 mm, from the Gulf of Spezia reveals good overall agreement of the main diagnostic characters. Some comparative observations (dimensions as thousandths of standard length; holotype cited first): length of head, estimated from figure, *ca* 178, 136; length to vent 458, 360 [in Scott 1983, p.189 incorrectly given as 146; this is mm not *TLs*]; length of caudal 186, *ca* 296; height of first dorsal 203, 617 [in Phillipps (1964) well in excess of *Ls*]; height of second dorsal near middle of body 79, 91; maximum depth 212, 156; length of pectoral 68, 56; length of ventral 167, stumps only [in some figured examples in excess of 400]; maxillary plate imperfectly delineated but clearly length greater than (approaching twice) width, 1.85; general outline of trunk subovate, trapezoidal, ventral contour much less boldly scalloped in holotype [in specimen *Ls* 120 mm, figured by Bachus *et al.* (1969) head and trunk together subrectangular with scalloping confined to subvertical hind margin; closest in outline to our specimen fig. 2 of Hamilton (1916)]; dorsal 6 + 114, 6 + *ca* 130-140 [second dorsal, Phillipps 111, Palmer 120-150]; no vesicles on fin rays, paired vestiges; color, fresh, wholly silvery, lacking markings, on collection pink and silvery grey, fins red, after preservation whitish or yellowish with some conspicuous dark brownish markings including three bars behind vent [similar markings depicted by Hamilton (1916, fig. 3), Phillipps (1944, pl.52), Fitch (1964, fig. 1), Bachus *et al.* (1969, fig. 2)].

Changes during development

Available evidence suggests the ontogeny of *Zu* is in general the same as that of *Trachipterus s.s.* The most noteworthy changes are the decrease in the size of the nuchal crest from a length exceeding that of the entire fish to less than that of head; decrease in relative length of pectoral and ventral, most pronounced in latter; separation of a horizontal caudal fin into a two-lobed structure, the upper fan-like, carried at an angle to the general anteroposterior axis, with subsequent complete or partial reverse of the process; elongation of posterior caudal vertebrae from subequal to the anterior to several times as long. Other changes include the loss of a filament in the ventral caudal lobe; degeneration of a physoclistic swim bladder to a small fibrous vestige; deterioration and

later loss of curious serially arranged structures borne on some fin rays, which at their maximum development take the form of membranous flaps enclosing a bean-like body, but later degenerate to small simple flaps, finally wholly disappearing or perhaps being represented by a patch of dark pigment. There appears to be quite considerable individual variation in the degree of development and in the rate of diminution of some of the structures here mentioned.

The only representative of the genus *Zu* hitherto known from Australia — New Zealand examples have been reported, under the names *Trachipterus jacksonensis* Ramsay, 1881 (in the present paper regarded as a senior synonym of *T. arawatae* Clarke 1881), *T. arcticus* Brünnich, *Desmodema arawatae* (Clarke, 1881) by Hamilton (1916), Phillipps (1944), McCann (1953), Whitley (1968) — a specimen from East Inlet, Stanley, Tasmania, described and figured by Scott (1983, p.188, pls 1,2) was there provisionally listed as *Zu* sp. cf. *Zu cristatus* (Boenlli, 1820). Reference to Bonelli's original paper, not then available, and to other relevant literature now leads to the conclusion this specimen is appropriately referred to Bonelli's extralimital species; and it is a purpose of the present communication to make this definitive attribution.

Lateral line

There is diversity, amounting to actual contradiction, in the accounts given by authors of the course of the lateral line (Scott 1983). Thus Palmer (1961, p.345) pictured the line as ending at a dorsoventrally contricted part of the fish just behind the vent. He wrote, "Lateral line armed, straight as far as the ventral construction where it joins the lower edge of the body." It is relevant to the discussion below to note that he continued, "Posteriorly from this point the ventral edge of the caudal region is armed with an additional paired series of downwardly directed spines, one on each side of the body." In contrast Walters & Fitch (1960, p.445) wrote "The lateral line is straight on the trunk, wavy on the tail, and extends onto the caudal filament between the rays where it is once more straight." In their key to families and genera of the Trachipteroidei (p.449) *Zu* was specified as having "lateral line wavy on tail." *Trachipterus* and *Desmodema* (also in the two accepted genera of Regalecidae) "lateral line straight on tail." Thus, if Palmer's specification is accepted, his fish is excluded from the family Trachipteridae as recognized by Walters & Fitch!

Figures by New Zealand authors depict the lateral line either ending shortly behind the vent — Phillipps (1944), McCann (1953, fig. 6), Whitley (1968, fig.1, main figure, not inset, which is a reproduction from Hamilton) — or more or less obviously continuing along the tail — Hamilton (1916). A plate by Bachus *et al.* (1969) labelled *Zu cristatus* shows no sudden dip towards the ventral border in the vicinity of the vent, and the row of spines on the trunk marking the course of the lateral line appears to extend in a continuous line on to the slender tail.

In a paper on ribbon fishes of the eastern Pacific Fitch (1964, p.230), after tracing the lateral line to the level of the operculum, observed, it "then progresses posteriorly in a relatively straight line, reaching the ventral contour about one-half head length behind the anus. From that spot to the caudal fin, the lateral line undulates as scales from opposite sides of the body align the ventral contour." A significant difference between the spines of the lateral line on the trunk and the spines on the tail, highly relevant as regards the status of the latter, appears clearly to have been recognized in the original description of *Trachipterus cristatus*.

While the position as depicted in Bonelli's (1820) illustration is not wholly clear, there would seem to be indicated a discontinuity of the line of spines on the trunk and the line along the ventral border of the tail, the latter continuing well forward beneath the former [as noted in his text (1820, p.489)].

A further examination of the specimen in the Queen Victoria Museum, *Ls* 405 mm, complements the earlier account (Scott 1983, p.191). As far as can be determined from this specimen: (a) the lateral line as found on the trunk in the form of a narrow groove armed with a row of small spines ceases some 15 mm, or less than half a head length behind the vent, terminating in an obscure irregular depression about 5-6 mm in length, lying within

2 mm of the ventral margin; (b) there is no effective junction between the structures on the two sides of the fish; (c) no extension of the groove caudad of the depression is evident; (d) several fine longitudinal grooves are detectable on the lateral surface of the tail, but none has any direct connection with the depression and two are traceable forward as far as the head, none bears spines; (e) the spines on the tail, some of which project below the lateral surface, appear not to be homologous with those occurring in the groove in advance of the vent on several counts, much larger, associated with large bucklers, no direct contact with lateral line of trunk; the foremost extending anterior to the termination of the obvious lateral line. On the evidence afforded by this individual, the probable conclusions are that the lateral line proper ends near the ventral margin shortly behind the vent and that structures behind this are not part of a normal lateral line. There remains, of course, the possibility, albeit unlikely, that two types of fish are indeed being treated by different authors as conspecific.

Attachment of dorsal membrane

In the descriptions of the type specimens of *Regalaecus* [*sic*] *jacksonensis* from Manly Beach Ramsay stated (1881, p.632) "The membrane between the dorsal rays is not attached to the back, but only at the base of each ray." Incidental mention was made in observations above on specimens in the Queen Victoria Museum, Launceston catalogued as Ramsay's species of its occurrence in the Museum's specimen of *Zu*. The lack of connection between membrane and body in the interval between rays is by no means conspicuous but is seen on close examination regularly to obtain. As far as the writer is aware this curious condition has not hitherto been reported in any descriptions of this species or depicted in illustrations of it.

FAMILY BOVICHTHYIDAE

Of the four families Nototheniidae, Bathydraconidae, Channichthyidae, Bovichthyidae comprising the suborder Notothenioidei, a group of primarily antarctic and subantarctic fishes, only the last — the name of which, partly as an outcome of the emendation by Agassiz (1845) of the type-genus *Bovichtus* Valenciennes, 1831 to *Bovichthys*, has appeared as Bovichthyidae (which has received the imprimatur of Greenwood *et al.* (1966) in their provisional classification of living teleosts), Bovictidae, Bovichtidae (adopted in the Checklist), Bovichthiidae — has ventured into Australian waters, although nine species of Nototheniidae are reported from New Zealand (Whitley 1968). All three Australian species are recorded from Tasmania, namely *Bovichthys variegatus* Richardson, 1846, *B. angustifrons* Regan, 1913 (the distinction of which from Richardson's species is not satisfactorily established), *Pseudaphritis bursinus* (Cuvier, 1830) (appearing in the Checklist (McCulloch 1929) as *P. urvillii* (Valenciennes, 1831); there treated as the sole representative of a separate family, Pseudaphritidae).

Observations on one or other of the Bovichthyidae appear in these contributions in Scott (1953, includes key to Tasmanian species; 1957; 1960; 1982).

Genus *Bovichtus* Valenciennes, 1831

Bovichtus Valenciennes, 1831, 8, p.486. Type-species *Callionymus diacanthus* Carmichael. Emended to *Bovichthys* by Agassiz (1845).

Bovichtus variegatus Richardson, 1846

(Text figs 2, 3)

Bovicthys [*sic*] *variegatus* Richardson, 1846, p.56, pl.39, figs 1-4. Type locality: Port Jackson, New South Wales.
Bovichtus variegatus: McCulloch, 1929, p.336: Parrott, 1948, p.145, pl.31, fig.4: Scott, 1953, p.155, and 1957, p.152.
Bovichthis [*sic*] *roseo-pictus* Hutton, 1904, p.148. Type locality: Sumner, New Zealand.
?Bovichtus angustifrons Regan, 1913, p.255, pl.4, fig.1. Type locality: Tasmania (one of two types without locality data).

Material

Six series collected in 1969 (one) and 1976 (five) at or near Greens Beach, northern Tasmania, by Mr R.H. Green, Zoologist, Queen Victoria Museum: (a) Greens Beach, collected 14 December 1969, 44 specimens, Q.V.M. Reg. No. 1972/5/167; (b) north of Greens Beach, 10 March 1976, 7, 1976/5/76; (c) 1.6 km north of Greens Beach, 24 March 1976, 43, 1976/5/88; (d) 1 km north of Greens Beach, 7 April 1976, 15, 1976/5/104; (e) 2 km north of Greens Beach, 16 April 1976, 69, 1976/5/118; (f) 3 km north of Greens Beach, 21 April 1976, 41, 1976/5/133.

Scope

A valuable biometric analysis of 30 specimens from eight localities in New Zealand and neozealanic islands has been provided by Parrott (1948). This was discussed by Scott (1953, p.155), comparison there being made of his data with (a) descriptions of the type specimens 200, 130 mm from Port Jackson, (b) Waite's (1909) account of a rock-pool specimen 55 mm long, (c) 11 examples obtained in 1952 by the use of derris in a single rock pool at Penguin, northwestern Tasmania, *Ls* 38.0-56.8, $\bar{x}$ 46.31±1.39 mm. The object of the present investigation is to extend and supplement the results noted in the 1953 paper, with special attention being paid to size classes, differential growth and some aspects of form. While material in the Museum's collection additional to that specified above, including series from the west coast and the east coast, has been looked at, only the 219 specimens from Greens Beach or nearby are here reported upon, advantage being taken of the excellent opportunity they afford to assess a population of this species from what is effectively a single locality. The present communication usefully complements the valuable data in Parrott's paper, in that the material here examined is all from a single locality, whereas of his 30 specimens 21 were from various localities in New Zealand itself and the rest from four different neighbouring islands.

Maximum size

The largest individual among the material listed above has a standard length of 127 mm, or 9.9% more than the next largest member of sample (f), or 24.2% above the average standard length of this sample; its total length is 147 mm: it is possible this specimen may belong to the next age class. The largest example in the Museum's collections, from Smiths Gulch, western Tasmania, has a standard length of 137 and a total length of 162 mm. Overall length is given by Johnston (single specimen) as 133 mm, by Waite (single specimen) as 55 mm, by Lord & Scott (1924) as 280 mm, by Scott *et al.* (1974) as 280 mm, by Last *et al.* (1983) as 300 mm: the largest example in New Zealand material discussed by Parrott had a standard length of 196 mm.

Abundance

Johnston (1883a) noted "rare" and (1883b) "extremely rare" but immature examples are often taken in the Derwent Estuary (Lord & Scott 1924). It is abundant in rock pools along the northern coast and at least in some parts of the west and east coasts. The sample of 11 juveniles from Penguin noted above was collected in a single pool with maximum dimensions of 2.6 by 1.7 m, where this species was associated with *Heteroclinus perspecillatus* Valenciennes, 1836, *Pictiblennius tasmanianus* (Richardson, 1849) *Creocele cardinalis* (Ramsay, 1882), and *Alabes rufus* (Macleay, 1881). [Last-named species identified — perhaps not altogether satisfactorily — by Springer & Fraser (1976) with *A. dorsalis* (Richardson, 1845)]. This fish is more or less cryptic, which may perhaps go some way to accounting for Johnston's unfamiliarity with it. With the advent of scuba diving it has become much more widely encountered. Last *et al.* (1983) rank it as among the most common fish found in caves and under ledges of shallow coastal reefs, noting small groups "are frequently seen by divers resting vertically or upside down on rock faces or pylons of jetties." The species is quite common and widely distributed in South Australia (Scott *et al.* 1974) and although the type locality is Port Jackson, New South Wales, McCulloch (1922) remarked that it has not since been recognized in that State and no specimens from the nominal type locality are present in the collections of the Australian Museum, Sydney (Dr J.R. Paxton, pers. comm.).

Standard length in present material

Among the 219 specimens of the six series here dealt with the standard length in millimetres ranges from 28 to 127, individuals of <33 being found only in (a) This series

TABLE 2

Bovichtus variegatus Richardson, 1846

Specification of standard length, mm, of 6 series, 219 specimens, from Greens Beach and vicinity, northern Tasmania.

Series	*N*	Range	$\bar{x}$	*V*
(a)	44	28-50	37.4±10.06	17.9
(b)	7	43.5-108	64.1±10.72	44.2
(c)	43	37-119	61.1±4.04	43.4
(d)	15	38-103	59.2±6.06	39.6
(e)	69	41-107	61.9±2.26	36.3
(f)	41	33-127	60.5±3.85	38.7

was collected in summer (December), the other five in autumn (March, April), and may be taken as including the youngest examples in the collection: of its 44 specimens, 10 measure 30 or less, and 25 are smaller than the smallest in the next series (10 March). "Juveniles are common in rock pools during autumn" (Last *et al.* 1983, p.426). The six series are specified for standard length in table 2.

Age classes

The high coefficients of variation there set out — *V* lowest, (a) 17.9 — are indicative of heterogeneity: in the absence of information on possible sex dimorphism this is here attributed to difference in age. Examination of all distributions reveals, first, a set of small individuals, A, with an *Ls* maximum of 60 mm, clearly separated by an interval of 13 mm from the next largest; secondly, a less decisive difference between a group of moderate-sized and a group of larger individuals. The point of demarcation between these latter two taken, somewhat arbitrarily in its precision but clearly valid in its general slope, is such as to yield in all three recognized size classes, here interpreted as year classes, A 28-60, B 73-87, C 88-127 mm. Ranges, means (with standard error), coefficients of variation for these are set out in table 3. The mean values may be empirically, if possibly somewhat adventitiously, specified thus (*N* = year number) $L = 120.16 \log N + 44.86$; t 64.328; predicted (measured) lengths, mm, 44.9(45.1), 81.0(80.5), 102.2 (102.5).

TABLE 3

Bovichtus variegatus Richardson, 1846

Standard length, mm, of three suggested age classes in 6 series, 219 specimens, from Greens Beach and vicinity, northern Tasmania.

Series	*N*			Range			$\bar{x}$			*V*		
	A	B	C	A (28-60)	B (73-87)	C (90-127)	A	B	C	A	B	C
(a)	44	0	0	28-50	-	-	37.4±1.01	-	-	17.9	-	-
(b)	5	0	2	43.5-50	-	103-108	47.6±1.13	-	105.5±2.50	5.3	-	3.4
(c)	29	6	8	37-57	73-87	92-119	46.3±1.05	79.9±2.01	105.9±4.16	12.8	6.2	11.1
(d)	10	3	2	38-50	77-85	100-103	43.9±1.22	82.3±2.67	101.5±1.50	8.8	2.2	2.1
(e)	46	14	9	41-59	73-87	90-107	49.3±0.72	79.9±1.03	96.6±1.84	9.9	4.8	5.7
(f)	31	3	7	38-60	80.5-82.5	94-127	47.1±0.80	82.7±1.48	105.7±4.65	9.3	3.1	10.1

Rate of growth

In the age classes A, B, C suggested above the absolute *Ls* increments, mm, are 35.4, 42.0, the percentage increases being 78.5, 27.3. If the largest individual in (f) is treated separately, the increase on the mean of (f) (without that specimen) is 25.4 mm or 2.5%. With presumed age of 1, 2, 3 years the age-length coordinates fall on what could well be the upwardly convex segment of the usual sigmoid growth curve.

Note on growth equations

Opportunity is here taken to make an observation, of some general relevance in a taxonomic context, on discrimination in the selection of an appropriate equation to represent data on growth. It is conventional in growth studies to use an asymptotic equation, chiefly because, as well as giving a reasonable fit to empirical data, it includes only three parameters, two of which (growth constant, asymptotic level) are interpreted as biologically meaningful — this advantageous feature has, however, been called into question

by Haukioja & Hakala (1979), who stated "the biological validity of comparisons of parameters derived from different populations is highly dubious."

Four asymptotic equations are in general use: von Bertanlanffy (1938) equation, usually presented (e.g. Ricker 1958) in the form

$$L_t = L_\infty(1 - e^{-K(t-t_0)})$$

where L = length of animal at time t, L_∞ = asymptotic length, K = growth constant, t_0 = theoretical time with zero length [four formal methods of solving the parameters are available; data by Haukioja & Hakala (table 2) show that for material examined by them of the values obtained for $S_{\%}\ \bar{x}$ three were 1.09, 1.52, 2.37 times that of the smallest]; Gompertz equation (Winsor 1932)

$$y_t = Y_\infty e^{-Be^{-Ct}}$$

where y_t = length of animal at time t, Y_∞ = asymptotic length, C = growth constant, B = a constant; logistic equation (Verhulst 1838)

$$y_t = \frac{Y_\infty}{1 + be^{-Kt}}$$

where K = growth constant, b = a constant; Kruger equation (Kruger 1962)

$$y_t = \frac{Y_\infty}{N(t + r)^{-1}}$$

where N = growth constant, r = a constant. For a given set of populations these four equations yield values of $S_{\%}\ \bar{x}$, and minimum and maximum values that exhibit not insignificant differences (Haukioja & Hakala, table 3). Of these equations that adopted by the great majority of Australian and New Zealand authors is the von Bertanlanffy.

On fitting polynomials up to the point at which adding a new term did not improve the result (upper limit is reached in 11 of 15 populations examined at a 3° equation). Haukioja & Hakala found "The mean $S_{\%}$ between actual and simulated [predicted] values was 1.28±0.690, a lower value than in any of the growth equations considered above (Table 2)"; the least value in that table, that arrived at by the iteration method, being 3.15±0.629 (other entries 3.42, 9.80, 7.46). They concluded "Therefore, with the present material, polynomials contained at most one or two parameters more than ordinary equations and were more accurate." In the light of the observations the writer was led three years ago to examine a number of von Bertanlanffy growth equations appearing in Australian periodicals accompanied by the primary measurements. In each instance it was found the fit provided by a polynomial of the form $Y = A+Bx+Cx^2+Dx^3+\ldots$ (usually of 3°) was better than that given by the published von Bertanlanffy equation.

The point to be made is this. While for purposes relating to general fisheries investigations, having in view the estimation and control of populations, for which a knowledge of the growth constant and the asymptotic level is of immediate significance, the use of one or other of the conventional asymptotic equations is appropriate; on the other hand if the primary aim is the provision for taxonomic purposes of the pattern of growth exhibited by a given sample, a more accurate representation of the measurements can be obtained by the use of a polynomial – a fact that has not always received due recognition in local literature.

Differential growth

Several features exhibit differential growth at different stages of development, conveniently investigated by assessing their relative magnitude, expressed as thousandths of standard length, as a ratio of standard length. The following results are based on measurements of 153 individuals (106A, 23B, 24C); except where otherwise indicated.

(a) Head. Relative, *TLs*, head length is inversely correlated with standard length, *Ls*, means for A, B, C being 432.1, 412.5, 405.3, respectively. In a series (a), which consists wholly of first-year individuals, the *TLs* mean is notably greater than the 432.1 for the general sample, being 475.3. For this ratio values have been calculated for all 219 specimens; these are 428.1, 412.4, 407.0. For these magnitudes and the first three noted above the negative correlation of log age with log length is 0.994, 0.993; values not sufficiently high, however, to yield a formally significant t with d.f.1.

(b) Length to vent. With A, B, C means 573.4, 572.3, 572.6 this remains significantly constant in the sample of 153 individuals. However, in (a), in which mean *Ls* is only 37.4, the low value of 540.6 is found; incorporation of this with the earlier value (weighted means) gives 569.2, the sequence A, B, C thus coming, at least formally, to be one of increasing magnitude.

(c) Length to first dorsal origin. As with length of head, length to first dorsal origin (this point anterior to opercular border) shows relative decrease with increase in overall size: A 323.4, B 314.1, C 298.3 (r −0.971).

(d) Length to anal origin. The correlation here is positive; and though C, 625.0, only marginally exceeds B, 624.9, both these are noticeably larger than A (smallest fish), 608.0.

(e) Maximum depth. With advancing age the fish decreases slightly in depth. For 77 A, 17 B, 16 C, the respective mean *TLs* values are 215.9, 205.4, 202.4.

(f) Lengths to pectoral, ventral origins. With pooled 17 C + 20 B compared with 75 A, larger values are met with among larger fish for both fins. Values for pectoral 331.4 and 304.8, for ventral 256.6 and 236.7.

(g) Length of pectoral fin. This has been examined in (e) (A 46, B 14, C 9), in which there is apparent a marked negative correlation between length of fin and size of fish, with means for A, B, C 347.5, 319.1, 308.2. With logarithms of both variates the plot is highly significantly linear (t 117.683**); predicted lengths 347.6, 319.0, 308.4.

(h) Length of ventral fin. With the same material as for the pectoral fin, the lengths for A, B, C are 282.7, 259.1, 248.3. A loglog plot of fin length on *Ls* is again significantly linear (t 19.309*); predicted lengths 283.0, 258.2, 249.0.

(i) Pectoral-ventral ratio. The pectoral is somewhat longer than the ventral. The relative lengths of the fins are close to constant, the measurements for the 69 fish of series (e) yielding A 1.231, B 1.236, C 1.242.

(j) Length of caudal. In series (c) total length is correlated inversely with standard length, length of caudal being 220.7 (220.5), 213.0 (213.5), 208.1 (208.0), the entries in parentheses being those yielded by a linear plot of length of fin on length of fish (intercept 230.2, slope −0.209, t 13.375). For the larger sample A is out of sequence being less than B, which, however, remains greater than C.

(k) Fin-body relationship. Since the fish as a whole is three-dimensional while the fins regarded as locomotory agents may be taken to be two-dimensional, the speculation presents itself: does some simple relation subsist between the volume of the body and the area of fin? As a gross approximation for investigation the volume may be taken to be a function of Ls^3 and the area a function of (fin-length)^2. For the pectoral the ratio Ls^3/P^2 for A, B, C is 0.992, 5.008, 9.489 (*Ls* in millimetres, fin length in *TLs*). This is correlated with *Ls* at r 0.980 (t 4.943), while the logarithmic values of the ratio give r 0.993 (t 16.064*). For the ventral the ratios are 1.500, 7.596, 14.619, correlated with *Ls* at r 0.978 (t 4.718), while the log values of the ratio give r 0.997 (t 13.768*).

(l) Growth in New Zealand material. In an examination of 30 specimens from seven localities in and around New Zealand Parrott (1948) observed of the pectoral, ventral and caudal "There appears to be a somewhat inverse correlation between the length of the fins and that of the fish. In younger or smaller examples the fins grow relatively fast in relation to body growth, while in older or larger individuals the reverse is the case. The Pectoral varied from 3.0 to 4.1 in standard length. The Ventrals are relatively shorter varying from 3.8 to 4.8 in standard length. The Caudal varied from 4.0 to 6.0." While there is a considerable amount of tabulated metrical data (tables 5, 6, 7) in this paper, the combination of small samples and diversity of source (attention is called at several points to differences in conformation of individuals from different localities), together with the presentation of proportions recorded only to a single decimal place is such that no statistically significant measures of correlation emerge.

Growth gradient

The gradient of growth along the anteroposterior axis of the fish is shown in fig. 2, where the lengths to the six morphological landmarks examined as found in sample A (smallest fish) are plotted along the lower line and the means of the pooled sample B (medium) and C (large) along the upper line; all dimensions as thousandths of standard length. The landmarks clearly divide into three pairs: (i) the paired fins, pectoral and ventral, the lengths to which are less in the larger than in the small fish; (ii) first dorsal origin and head (opercular margin) with values greater in the larger fish; (iii) vent and adjacent

anal origin with, at hinder end of fish, values again less in the larger fish. With the item for (B + C), mean, expressed as a percentage of that for A, the values for the members of each pair are virtually the same — ventral origin 92.5%, pectoral origin 92%; first dorsal origin 105.7%, head 105.7%; vent 98.1%, anal 97.3%. A striking feature is the intersection of the lines for pectoral and first dorsal, the pectoral, inserted posterior to the first dorsal in the young fish, coming to lie in front of it in the older. The paired fins thus appear to be under the control of a growth mechanism different from that governing the other features considered. An example of variation in fin sequence in another Tasmanian fish has been noted by Scott (1978). In *Schedophilus huttoni* (Waite, 1910) the dorsal origin migrates from a position in advance of pectoral origin in young fish to above that fin in older fish: exchanges of serial order are known to occur in other members of the Centrolophidae (Haedrich 1967).

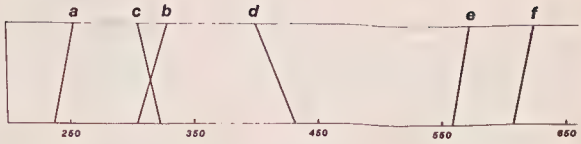


FIG. 2 - *Bovichtus variegatus* Richardson, 1846. Relative growth as indicated by relative length, thousandths of standard length, to six morphological landmarks along anteroposterior axis of fish. Lower line size class A (smallest); upper line size classes B (medium) and C (largest) pooled (size classes specified in table 3). Points of measurement: a, length to ventral origin b, length to pectoral origin; c, length to first dorsal origin; d, length of head (to opercular border); e, length to vent; f, length to anal origin. Note sequence of ascending magnitude a, b, c, in smaller individuals becomes a, c, b in larger.

Though the variations with age in the location of these morphological points along the anteroposterior line constitute quite definite divergences, the differences involved are not very large. While the plot of all the pooled items for B and C on the corresponding items for A can plausibly be dissected into an anterior section and a posterior section with steeper slope, nevertheless it presents overall a very good approach to a single straight line (t 7.690**), with a slope, 0.933, not far from unity. The fact that the intercept is small, 30.4, suggests examination of the data with the inclusion of a point with zero coordinates. Such a line has a slope of 0.985 and a negligible intercept of 0.7; the correlation coefficient is 0.996, equivalent to a t value of 24.509***.

Depth-width relationship

In the course of an examination of two large examples of the other Tasmanian bovichtyid, *Pseudaphritis bursinus* (Cuvier, 1830), *Ls* 185, 225 mm, there emerged an interesting relation between depth and width. With ten widths, measured at equal intervals along the anteroposterior axis from most advanced point to hypural joint, plotted against ten depths similarly measured, the plot assumes a sublenticular form, with an upwardly convex curve for the early deciles, terminating near, or on extrapolation becoming continuous with, a longer upwardly concave curve for the later deciles (Scott 1982, fig.8a). Each segment represents a logarithmic arc such that log W = mD + c (1982, fig.8b). In the present species with ten pairs of similar measurements the width-on-depth graph again presents a precise pattern, with two curves converging, here intersecting, at decile 3. There are, however, noticeable differences from the earlier formulation: first, the arc for deciles 1-3, convex in the other species, is here concave; secondly, the segment for deciles 4-10 {3-10}, in *Pseudaphritis* represented by a single arc, here takes the form of a continuous curve resolvable into two segments, one upwardly convex for deciles 3-7, one upwardly concave for deciles 7-10: i.e. in *Pseudaphritis* A {1-3} $\cap$ B {3-10}, in *Bovichtus* A {1-3} $\cap$ B {3-7} $\cap$ C {7-10}. As before in each set log W = mD + c. Measurements of depth and width, as *TLs*, together with the rectified equations for each of the three arcs, accompanied by values predicted by these equations, with an indication of significance are set out in table 4. Graphs for two specimens are presented, one (fig. 3A) for an example of *Ls* 52 mm, the other (fig. 3B) for an example of *Ls* 110 mm, both with eye-fitted curves. It will be seen these exhibit a striking difference, that for the small individual having the curve for {1, 2, 3} above the sigmoid curve, that for the larger individual having the former below the latter. The difference relates to the size of the fish, the situation

TABLE 4

Bovichtus variegatus Richardson, 1846

Depth-width relationship, Log W = m D + c, for five specimens of standard length 52-119 mm; ten measurements of depth and width taken at equal intervals between most advanced point and hypural joint. For each individual three sets, specified by the numerical value of the decile measurements thus {1-3}∩{3-7}∩{7-10}.

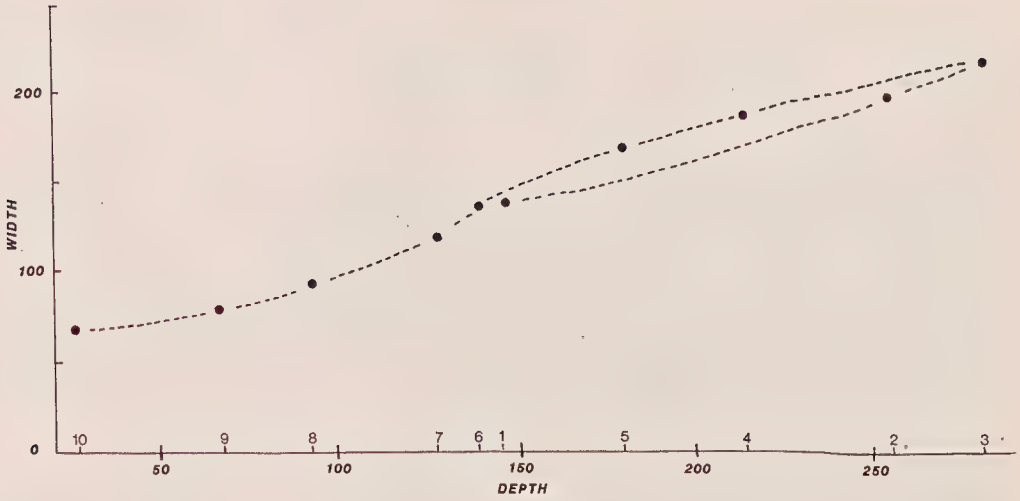
Ls, mm	Decile set	Log W = m D + c $m \times 10^3$	c	Depth, *TLs*	Estimated (measured) width, *TLs*	*t*
	{1-3}	3.024	1.7792	116,183,196	134(135),215(211),236(238)	22.808*
	{3-7}	6.118	1.861	196,185,173,152,137	243(238),207(212),176(173),130(137),105(102)	18.158***
52	{7-10}	2.558	1.6609	137,87,63,58	102(102),76(77),67(67),64(62)	25.437**
	{1-3}	3.167	1.7159	128,190,206	132(132),207(210),232(231)	24.025*
	{3-7}	3.632	1.5993	206,181,154,136,123	222(231),180(173),141(141),124(122),111(115)	13.816***
78	{7-10}	6.806	1.2345	123,101,77,54	118(115),84(85),57(64),40(38)	17.110**
	{1-3}	1.245	1.9744	145,182,200	141(145),185(182),197(200)	9.453
	{3-7}	0.846	2.1007	200,202,182,168,155	208(200),193(202),180(182),167(168),159(155)	5.600*
110	{7-10}	4.667	1.6362	155,127,84,64	154(155),127(127),86(84),63(64)	33.41*
	{1-3}	1.326	1.9501	147,256,283	142(142),198(198),215(216)	144.334**
	{3-7}	1.517	1.9269	283,216,181,140,120	227(216),179(187),159(171),138(138),129(121)	6.699**
116	{7-10}	2.602	1.7506	120,93,69,28	116(121),98(95),85(82),67(69)	7.497*
	{1-3}	1.634	1.8648	151,218,227	151(151),217(218),228(227)	39.920*
	{3-7}	0.667	1.1631	227,214,216,185,174	232(227),212(214),199(206),187(185),176(174)	8.361*
119	{7-10}	4.310	1.6774	174,109,101,66	164(174),119(109),101(101),63(66)	9.107*

obtaining in the smaller specimen being duplicated in that for a second small specimen of *Ls* 78 mm (the upper curve here approaching closer to the lower than in the specimen of 58 mm), the situation found in the larger fish of *Ls* 110 mm repeated in other large individuals of *Ls* 110, 119 mm.

FAMILY ANTENNARIIDAE

History of family in Tasmania

Important items in the history of this family in Tasmania include the following. (a) No antennariid noted in first two Tasmanian faunal lists (Johnston 1883a, 1891). (b) *Antennarius mitchellii*, type locality Lisdillon, eastern Tasmania, described by Morton (1897, XIV and p.98) [second binomen cited incorrectly in Checklist (McCulloch 1929, p.408) as *mitchelli*; this emended form being there adopted and receiving subsequent general currency]. (c) Morton's fish nominated as type-species of genus *Trichophryne* (McCulloch & Waite 1918, p.68, pl.6, fig.1) and reported from South Australia and Victoria. (d) Third Tasmanian catalogue (Lord 1923, p.71) lists *Trichophryne mitchelli* [*sic*] and *Histrio histrio* Linné [this species, widely distributed in the Atlantic, east and west Pacific and Indian oceans, is formally recorded from Australia in the Checklist only from New South Wales; no locality record is given by Lord, and it is here suggested its inclusion in the local list is probably an error]. (e),(f) The subsequent catalogues of Lord & Scott (1924, pp.14, 89) and of Lord (1927, p.16) repeat the two entries of Lord (1923) without comment. (g) *Rhycherus filamentosus* (Castelnau, 1872), with type locality St Vincents Gulf, South Australia, added to Tasmanian list by Scott (1935, p.71, pl.5, fig.2), specimen from Tamar Heads, northern Tasmania. (h) *Echinophryne crassispina* McCulloch & Waite, 1918 added to Tasmanian list (Scott 1978, p.312), this species up to now represented locally only by this specimen, from east coast of Flinders Island, Bass Strait. (i) A fourth species, listed as *Trichophryne furcipilis* (Cuvier, 1817) reported in Last *et al.* (1983, p.256, fig.22.8) [observations made below on this species and its generic identity discussed].



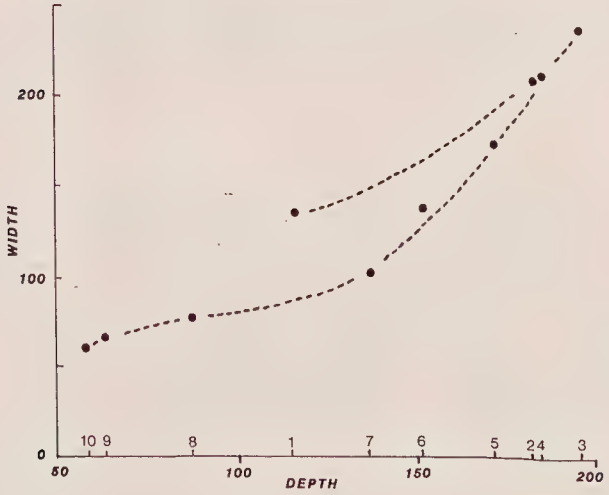


FIG. 3 - *Bovichtus variegatus* Richardson, 1846. Width (vertical axis) at ten equidistant points (1-10) between tip of snout and hypural joint on depth (horizontal axis) at same points; dimensions as thousandths of standard length. Two specimens from Greens Beach. A (bottom graph), standard length 52 mm, B, 116 mm. Curves eye-fitted (each figure with three logarithmic arcs).

Species known to occur in this State may be distinguished by the subjoined key.

KEY TO TASMANIAN ANTENNARIIDS

1. Skin smooth. Body and second and third dorsal spines with long cutaneous processes. Second dorsal spine shorter than first. Lure larger than eye-diameter. Size larger, length to about 250 mm. ..... *Rhycherus filamentosus*
   Skin with minute spines or bristles. Body and second and third dorsal spines without long cutaneous processes. Second dorsal spine (full length) as long as, or longer than, first. Lure smaller than eye-diameter. Size smaller, length to about 150 mm 2
2. Second dorsal spine conical, attached behind in its basal half or more to dorsum, shorter than longest dorsal ray. Second dorsal with 15 rays. ..... *Echinophryne crassispina*
   Second dorsal spine rodlike, not attached behind in its basal half to dorsum, longer than longest dorsal ray. Second dorsal with 13-14 rays. 3
3. First dorsal spine covered with delicate skin, bearing bristles forming a cluster at its tip. Second spine similar to first but with larger bristles. Free portion of third spine shorter than snout. ..... *Trichophryne mitchellii*
   First dorsal spine naked, glassy. Second spine much stouter than first, with bristles and usually a few longer fleshy processes. Free portion of third spine longer than snout. ..... *Kuiperichthys furcipilis*

Distribution

The Tasmanian component of the Australian antennariid fauna presents an interesting chapter in zoogeography. Since the pioneer investigations of Hedley (1904), working on mollusca, it has been recognized the waters around Australia divide into regions, each characterized by a more or less distinct fauna; significant contributions to their specification having been made by, among others, Iredale (1937) (molluscs), Kott (1952) (ascidians), Endean (echinoderms), Whitley (1932, 1937) (fishes) — for other references including some by overseas authors, Whitley (1964, p.23) may be consulted. In broad terms the coastline is classified thus: from Shark Bay and Cape Jaubert in Western Australia north and east to Cape York, Damperian; Queensland, Solandrian; south along New South Wales to southern Tasmania, Peronian (with Maugean subregions on Tasmania's east coast, extending northward, for some faunas as far as Port Jackson); from D'Entrecasteaux Channel along the Tasmanian west coast, Victoria, South Australia, south and southwestern coasts of Western Australia, Flindersian. As observed by McCulloch & Whitley (1958) "The marine fish fauna of Australia is composed of three elements — species derived from the north, southern forms and deep-sea types", an arbitrary line of division being set at 27°S.

Among the Antennariidae the genera *Antennarius* Lacépède, 1798 [in the Australian Checklist (McCulloch 1929) genus attributed to Cuvier, 1816], *Phrynelox* Whitley, 1931, *Lophiocharon* Whitley, 1941 (these two included by early writers in Lacépède's genus) and *Tathicarpus* Ogilby, 1907 are warm-water genera, confined in Australia to the northern Peronian, the Solandrian and the Dampierian regions, with a number having also a wide extralimital distribution. On the other hand the genera *Rhycherus* Ogilby, 1907, *Echinophryne* McCulloch & Waite, 1918, and *Trichophryne* McCulloch & Waite, 1918 are inhabitants of the Flindersian and Peronian regions, to which the first and second are endemic, as also possibly is the third, a Philippine Islands species described by Smith (*in*: Smith & Radcliffe 1912) as *Antennarius rosaceus*, but referred by Schultz (1957, 1966) to *Trichophryne* differing in several noteworthy features from the type-species of that genus (*Antennarius mitchellii* Morton, 1896, from Tasmania) and being doubtfully congeneric with it.

Thus in general the Australian antennariids divide into northern and southern genera; many representatives of the former being tropical forms with Australia on the southern

fringe of their distribution, whereas the latter lack any components from the south, the New Zealand fauna for instance including a single species, the widespread *Phrynelox striatus* (Shaw & Nodder, 1794), the type locality of which, rendered "Circa litora Australasiae" by Banks, is identified by McCulloch (1929, p.407) as Botany Bay, New South Wales [for status of *Antennarius pinniceps* Commerson, 1837 *vis-a-vis* this species see McCulloch (1922, p.123) and De Beaufort & Briggs (1962, p.213)]. The genus *Histiophryne* Gill, 1863 as recognized in Australia poses a problem.

The South Australian fish described and figured by McCulloch & Waite (1918, p.74, pl.7, fig.2) as *H. scortea* (of which a variety, *H. s.* var. *inconstans*, is noted) presents — as pointed out in De Beaufort & Briggs (1962, p.220) — some noticeable differences in the character of the second and third dorsal spines from the fish described and figured by them (p.72, pl.7, fig.1) as *H. bougainvilli* Valenciennes, 1837 (type-species of *Histiophryne*), and indeed from extralimital species that have been referred by other authors to Gill's genus. The provenance of the specimen illustrated in fig.1 is unknown (may not even be South Australia); and the possibilities arise, first, that Gill's genus may not be represented in South Australia, secondly that material described as *H. scortea* may properly be referable to a separate endemic genus of the Flindersian region.

Genus *Kuiterichthys* Pietsch, 1984

Kuiterichthys Pietsch, 1984, 1, p.37. Type-species *Chironectes furcipilis* Cuvier.
Chironectes Cuvier, 1817, 3, p.418. Type-species *Lophius chironectes* (Commerson) Lacépède.
Batrachopus Goldfuss, 1820, 2 (3), p.110 — substitute name for *Chironectes* Cuvier, 1817.
Capellaria Gistl, 1848, p.8 — substitute name for *Chironectes* Cuvier, 1817.

Kuiterichthys furcipilis (Cuvier, 1817)

(Plate 3)

Chironectes furcipilis Cuvier, 1918, p.329, pl.17, fig.1. "On ignore d'où cette espèce est venue au cabinet." Known distribution: from central New South Wales to just east of the Recherche Archipelago and Tasmania, in depths of 9-24 m (R.H. Kuiter, pers. comm.).
Trichophryne furcipilis: Last *et al.*, 1983, p.256, fig.22.8.
Kuiterichthys furcipilis Pietsch, 1984; p.37.

Tasmanian history

The account of the species here presented is a revised extract from an unpublished review of the Tasmanian Antennariidae carried out by the writer during the seventies, it therebeing treated as an undescribed species. Shortly before the deadline for submission of this Ms there appeared in Last *et al.* (1983, p.256, fig.22.8) an account and figure of it under the heading *Trichophryne furcipilis* (Cuvier, 1817), the entry, Dr Last informs me, having been supplied, on the basis of Tasmanian material made available to him, by Dr T.W. Pietsch. At that time, in the course of a revision of the Australian Antennariidae, he was contemplating referring Cuvier's species to a new genus, *Kuiterichthys*; now published (Pietsch 1984), the genus being monotypic, locality of holotype knknown. It was indeed evident that with its naked glassy first dorsal spine it could not legitimately be placed in *Trichophryne*, a diagnostic feature of which is the presence of bristles on that spine (a character that appears in part to have suggested the use of the prefix "tricho-", signifying "hair" or "hairy").

The second binomen *furcipilis* does not appear, either as a valid or a synonymic taxon, in any of the comprehensive catalogues of Macleay (1881-1884), McCulloch (1929), Munro (1956-1961), Whitley (1964), the fact that the source of the holotype was unknown having led to the failure of the fish to be noted in local literature till quite recently. Cuvier's own vernacular "La Chironecte a poils fourches" suggested the latinized version (literally, "fork-skinned"), alluding to the presence on the skin of fork-like (bifurcate) spinous processes, developed on tubercles. *Chironectes furcipilis* is given by Schultz (1957, p.73) as a queried synonym of *Phrynelox scaber* (Cuvier, 1817), with type locality Atlantic; but it is clearly distinct from that species.

Distribution

Last *et al*, stated "This species is common in D'Entrecasteaux Channel [southeastern Tasmania] on muddy bottoms in depths between 15 and 50 metres. It is occasionally found in the catches of scallop dredges." Mr R.H. Kuiter, Seaford, Victoria, in whose honour the species is named informs me (*in litt.*) "It occurs along our south coast from central New South Wales to just east of the Recherche Archipelago and Tasmania."

Material

Specimen (a), *Ls* 113 mm, *Lt* 140 mm, dredged in D'Entrecasteaux Channel, October 1921 (Tasmanian Museum and Art Gallery, Hobart; D365; identified as *Echinophryne mitchelli*); (b) *Ls* 80 mm, *Lt* 99 mm, dredged in D'Entrecasteaux Channel near Kettering (Tasmanian Fisheries Development Authority; collected by J. Lion and T.L. Seward, 8/10/1935).

Meristic characters

D. 1, 1, 1, 13. A. 8. P. 10. V. 5. Fig. 22.8 in Last *et al*. (1983) appears to depict an unexplained total of 6-7 rays in the ventral.

Dimensions

All "length to" measurements are taken from the most advanced point on chin: in (a) this is 2.5 mm (22 *TLs*) in (b) 1.5 mm (19 *TLs*) in front of tip of upper jaw. Length to base of caudal, *Ls*, (a) 113 mm, (b) 80 mm, to end of caudal, *Lt*, (a) 140 mm, (b) 99 mm. All dimensions that follow are recorded as thousandths of standard length, *TLs*; specimen (a) recorded first. Length to felt-for operculum 354, 300; to felt-for preoperculum 265, 225. Length to gill opening 469, 413; free length of branchial tube 35, 35; diameter, longitudinal 18, 26, transverse 27, 31. Length to fleshy eye capsule, full 93, 88, from tip of upper jaw 64, 69. Diameter of ocular capsule 73, 94, of exposed eye 40, 50. Interorbital, capsule 124, 65; eye 133, 90. Length of maxilla 208, 186; maximum width 66, 51; shortest distance from eye (capsule) 36, 25. Maximum (median) width of lower lip 27, 26. Width of mouth at angle 265, 250. Length to anterior nostril 22, 19; internarial (anterior nostrils) 62, 58. Length to first dorsal spine, 22, 19; length without lure 168, 156; length with lure 204, 179; transverse extension of lure 36, 50; basal diameter of spine 4.4, 4.4. Length to second dorsal spine 71, 88; length of spine 132, 188; basal diameter 26, 24. Length to third dorsal spine 221, 194; length, total 168, 150, free of membrane 80, 100; total longitudinal extent of membranous base 115, 125. Length to first dorsal ray 434, 369; to last ray 885, 794; base, between parallels 451, 425; direct, ray to ray 473, 450: for lengths of dorsal rays see below. Length to first anal ray 699, 656; to last ray 916, 819; base, between parallels 217, 163; direct, ray to ray 226, 175: for lengths of anal rays see below. Length to vent 673, 619. Length to origin of ventral 164, 106; length to base of first ray 190, 138; oblique length of base 97, 81; interval between bases of first rays 106, 94, between bases of last rays 133, 125: for lengths of rays see below. Length to felt-for pectoral origin 265, 250; length of distal segment of pseudobrachium from base of gill tube to tip of longest ray 319, 263; total length of pseudobrachium straightened out 425, 313: for lengths of rays see below. Depths (in parentheses widths) at front of eyes 292(204), 275(213), at back of eyes 354(292), 325 (281); at operculum 451(425), 400(306); at first dorsal ray 442(407), 375(202); at vent 310(195), 275(139); at anal termination 168(124), 119(67); caudal peduncle, minimum dimensions 140(33), 110(24). In view of the flabby character of the skin, some of these measurements of depth and width are to be regarded as being best estimates.

Proportions

Some standard proportions may be noted. In standard length: head 2.8, 3.3; length to vent 1.5, 1.6; maximum depth 2.2, 2.5. In head: snout, from tip of upper jaw 6.6, 6.0, full 5.0, 4.7; eye, capsule 6.5, 4.4, exposed organ 11.8, 8.3; interorbital, capsule 6.5, 4.4, eyeball 8.5, 8.3; caudal peduncle, length 5.6, 2.3, depth 3.4, 3.8.

Description

(a) General form. The account in this section is based primarily on the larger individual. Stout, subequal height and width about half standard length, elevated in front, tapering tolerably evenly behind. Dorsal profile: upper lip rounded, a short subvertical segment between mouth cleft and base of illicium, thereafter slightly convex to origin of second spine, overall angle about 45°; between bases of second and third spines

PLATE 3 - *Kuiterichthys furcipilis* (Cuvier, 1817). Dredged in D'Entrecasteaux Channel, southeastern Tasmania, October 1921, standard length 113 mm; Tasmanian Museum and Art Gallery, D365, labelled *Trichophryne mitchelli* (Morton, 1897). Photo: M. Bartkevicius.

virtually horizontal; third spine running obliquely backward, its anterior contour moderately convex, the somewhat recurved tip above the back by about two-fifths chord of anterior border or a little more than preorbital length, membrane of posterior border strongly backwardly concave; highest point on outline of fish near its point of attachment; between third spine and first ray virtually straight, sloping back at an angle of some 20°-25°; base of soft dorsal sloping steeply down, barely convex; caudal peduncle slightly convex anteriorly, almost straight for most of its length. Ventral profile: between lower lip and insertion of ventral fin moderately round, more markedly in lower half; thereafter to vent virtually horizontal; a single convex sweep from anal origin to caudal origin, tending to straighten out on peduncle. Ventral surface between level of ventral fins and anal almost flat; some slight convexity transversely, barely recognizable longitudinally. The combination of plane under-surface and low centre of gravity makes the fish highly stable on a flat surface, considerable force being required to disturb its equilibrium. Caudal peduncle distinct, stout, its width at end of anal base subequal to its depth at caudal origin, its anterior depth about one and a third times its anterior width, which equals two-thirds anal base.

(b) Head. Large, 2.72 in *Ls*, subglobular, its width barely greater than its depth, the later 1.16 in its length. Operculum and preoperculum wholly enveloped in skin, the opercular region rounded and noticeably elevated, separated by a slight depression from a less prominent bulge below whole base of third dorsal spine. On right side of fish two rather obscure longitudinal ridges, somewhat upwardly and backwardly oblique, each with several papillae bearing a slender tentacle, either simple or, more commonly, branched distally. Viewed from above the region between the second and third dorsal spines, more or less horizontal in lateral aspect, bears three longitudinal ridges extending back

from base of second spine, a medial and two lateral ones, the latter diverging backward, their distance apart behind more than one and a half times that in front, subequal to their own length or half length of second spine; this area, more or less a walled subtriangular platform, is slightly concave transversely on either side of median ridge. Eye about level with upper lip and with nostril, its shortest direct distance from mouth subequal to that from base of second spine; the visible part of the ocular organ wholly surrounded by an elevated circular fleshy capsule more than half as wide again, its height subequal to eyeball diameter; top of capsule beset with upwards of a dozen short radial ridges, each bearing several, modally half a dozen, short tubercles or longer processes, at times bifid distally; at upper border of capsule two ridges markedly higher and longer than rest extend inwards from the orbit, these heavily papillate structures coming to interrupt the general flattish profile between the second and third spines, rising above the longitudinal ridges. Mouth large, almost vertical, slightly downwardly and backwardly oblique, extending to below about middle of eye; upper lip tumid, of approximately constant width throughout; lower lip bolster-like, especially laterally, widest anteriorly, there almost twice upper lip; both lips received laterally into a pouch with proconcave opening, its walls smooth wholly lacking the spinules abundant on adjacent integument; lower lip here and for some little distance forward overlapping the upper; on right side near its middle a row of eight minute tubercles not evident on left side. Maxilla rounded distally. Narial system consisting of two small tubes about as wide as high set on a subcircular mound flanking base of first dorsal spine at level of middle of eye, from which the posterior is distant by half diameter of eye capsule; anterior directed forward overhanging mouth, its aperture flaring, posterior directed upward, its orifice somewhat constricted. A small rounded obscurely nodulose white papilla on summit of small fleshy mound medially in upper jaw, continuous on either side with upper lip. Teeth in lower jaw of variable size, in up to three rows, closely set, interspace equal to or, more commonly, slightly less than, basal diameter, latter about one-third height; slender, conical, mostly acutely pointed, directed upward and backward. Teeth in upper jaw very irregularly arranged in 1-3 imperfect rows, in outermost row some small, some minute; largest subequal to largest of lower jaw. Behind a gelatinous frenum an obliquely transverse group of about a dozen teeth, variable in size, on each palatine; several more, in general similar, on vomer. Tongue with scattered white papillae, simply rounded or rounded with central conical projection; no glossal teeth observed. For spinulation see next section.

(c) Body. Together with most of the head the trunk and tail are covered with spinules, small, closely set, upwards of a hundred per square centimetre on the flank and twice as many on the belly. They exhibit both regional and individual variation. Typical examples on the flank, standing more or less erect or directed somewhat backward, are subtrapezoidal, the distal (greater) width ranging from subequal to the length to less than two-thirds of it; the free margin is crescentic, being produced laterally into short acute points (Cuvier's "villis bifurcis"). On the ventral surface in all but the most anterior part of the head, on the whole of the trunk and on the anterior one-third or so of the tail they lack the points, being reduced to subcircular flattened ossicles suggestive of paving stones. They extend on to the second and third dorsal spines and on to all rayed fins, where they are most densely set along the rays. In certain areas, notably the anterior one-fourth of the soft dorsal and a patch beneath the eye, they are interspaced with or replaced by single-pointed subconical projections; along the anterior margin of the dorsal rays these develop fine bristle-like terminal prolongations. On the odd-numbered rays of the caudal they become very closely set in the basal half or more, beyond which they tend to form two distinct linear series, this condition being found throughout the length of the even-numbered rays; this pattern is less clearly developed in the smaller individual. In the paired fins spinules are confined to a small proximal area, except upon the outer surface of the pectoral where they extend linearly along the rays. Individual variations within groups are commonly only matters of size and proportion, but here and there an ossicle with a single projection appears among others of modal bifurcate form. In the smaller individual the general situation is closely similar to that in the larger; however the concavity of the distal margin is regularly deeper and the two tips are more decisively produced.

In addition to the spinules the integument bears a number of small slender fleshy projections. Of these some are quite irregularly disposed, their development being apparently adventitious: thus while the second dorsal spine of specimen (a) bears two pairs, each about one-fourth as long as the spine, the third bears three, somewhat smaller; none occurring on either spine in (b); indeed, such appendages are in general almost non-existent in (b), in which even the course of the lateral line is not evident. In (a) the lateral line, beginning below the end of the end of the membrane of the third dorsal spine, level with the upper margin of the fleshy ocular capsule runs back almost parallel with the dorsal contour, though progressively approaching it caudad, to end at base of second caudal ray. Its course is marked by a number of processes usually subcylindrical or vermiform, occasionally branched. Two series originating at the middle of the chin curve up to define the posterior margins of the preoperculum and operculum; additional scattered examples occur between these from about the level of the lower border of the orbit down to the upper insertion of the pectoral. Other tentacles, isolated or in small groups, are found on either lip; below the angle of the mouth (on left side largish multifid tentacle, on left several small dense tufts); tentacles and tufts above the orbit; a pair of wide flat branched tentacles on either side of base of first dorsal spine (illicium), bending inward to meet above its base; numerous elongate slender vermiform processes on lower surface of the ventral and the pectoral; a few also on the caudal.

The vent is a small circular aperture, enclosing a small papilla; in (a) it is preceded by a proconvex arc of elevated skin. The relative positions of end of head, vent, caudal origin are adequately specified by the equation log L = m log N, where L is length to feature (here *TLs*) and N is log {1,2,4}. For (a) the value of m is 0.5462, for (b) 0.6379; c is 2.6686, 2.6105; t 37.571*, 23.338*; mean difference between predicted and observed widths 1.5%, 1.6%.

(d) Fins. The illicium, arising from a small rounded fleshy elevation contiguous with the upper lip, barely separated on either side by a narrow tentacular tuft from a globose enlargement bearing both nostrils, is cylindrical, slender almost filamentous, narrowing somewhat distally, wholly smooth, glassy, flexible; its length in (a) a little greater than, in (b) a little less than, that of the second spine. The lure, with mass much exceeding that of the stalk, consists primarily of two apposed main lobes together forming a crescent with its free distal border briefly incised at their junction (a) or (b) there giving rise to a third process, bluntly bifid; the two lobes of the crescent in (a) very stout with width about half length, but in (b) slender tapering processes; in (a) the arms minutely tuberculate and with several insignificant secondary processes, in (b) the processes obscurely noded. Second spine stout (a), fairly stout (b), enclosed in (a) in thick, in (b) in more delicate, skin; in both specimens beset throughout with tubercles, spinules or processes, in (a) two pairs of prominent fleshy processes, in (b) processes, fine, many elongate spine-like, highly acute; tip in (a) somewhat lobate, distinctly so in (b). Third spine stouter than second, somewhat longer (a), somewhat shorter (b), than it; wholly enclosed in integument liberally beset with spinules, in (b) most, especially distally, very slender, acute; in (b) no appreciable membrane developed, but in (a) — as in figures by Cuvier and Last *et al.* — a distinct fold behind, here arising at basal one fourth of height and extending back close to halfway to base of first dorsal ray, its free border concave. Soft dorsal with 13 rays; length of its base in (a) subequal to, in (b) distinctly more than, distance of its origin from tip of snout; fairly elevated; ray tips pointed, as preserved recurved, strongly so in (b), bifurcate spinules along their length, forming a line along anterior border of free portion in (a), in (b) here usually taking the form of a series of very fine bristles; spinules on rather fleshy membrane largely restricted to basal half; in most of the fin membrane distinctly incised, barely so between last three rays in (b) last four in (a); all rays simple, except 10th of (a), which gives rise in its distal one-fourth to a backwardly directed spur, its form and position somewhat suggestive of its being an abnormal development.

Anal subequal in height to dorsal, originating beneath its middle, terminating shortly behind it; differing noticeably in general appearance in the two specimens; rays in (a) encased in thick integument, barely extending beyond the membrane, the tips blunt, even somewhat spatulate, it not being possible to ascertain whether or no they are divided, in

(b) first three only slightly, rest well beyond the membrane, 4th, 5th, 6th terminally bifid, the tips of the rami projecting as slender points. Ventrals with five rays, inserted well forward, origin below eye; fairly close together, hind contour of bases clearly continuous in (b); separated, extend beyond outer border of ventral surface in (b), fail to do so in (a); rays wholly enveloped in integument; except for first two preaxial in (a), which are bluntly rounded distally, tips pointed, in (b) acutely, not divided; membrane incised, most markedly postaxially. Pectoral with ten undivided rays; with distal segment of pseudobrachium extended at right angles to anteroposterior axis of fish, its anterior border about level with origin of soft dorsal; rayed portion large, its area in (a) about twice in (b) about thrice area of ventral; rays very fleshy, extending well beyond membrane, particularly postaxially; tips slender tapering to acute points in (b), stouter, less sharply pointed in (a). Anal with eight rays, rounded in (a), imperfect in (b); all rays except uppermost and lowermost divided, modally for about one-fifth of length; membrane in general not, in parts slightly, incised.

The lengths of all rays other than those of caudal (fin imperfect in (b), not satisfactorily measurable in (a)) are recorded in table 5. They present a common pattern, increasing to before or beyond the middle one, then decreasing regularly. In a loglog plot the lengths of the ascending set are a linear function of the serial numbers of the rays counting caudad, those of the descending set a linear function of serial numbers counted cephalad, i.e. $L = b\ N^k$, where L is length, N a natural number indicative of serial position, the exponential formulation on rectification yielding a linear graph. Table 5 sets out the parameters of the rectified equations and predicted and measured lengths, accompanied by an indication of statistical significance. The patterns in the two specimens are the same with one exception, the maximum height of the anal occurring at the 6th ray in (a) at the 5th in (b).

Coloration

The ground color, noted by Last *et al.*, presumably with reference to fresh material, as whitish or pinkish, is in (a) dark brownish in the anterior two-thirds, lighter behind, in (b) more or less uniform faintly purplish dark grey. Ventral surface pale yellowish (a), whitish (b). "Margin of soft dorsal fin blackish or purplish" (Last *et al.*): (a) without ornamentation; (b) with conspicuous blackish tips to last seven rays, the marking progressively becoming more extensive caudad, finally involving one-third length of fin. Spot on base of dorsal reported as usually present occurs in (b), quite conspicuous near end of anterior one-third of base, rounded, blackish, extending briefly on to dorsum, absent in (a). Specimen (b) without noticeable body markings, but (a) with numerous small rounded dark brown or rufous spots, most evident in hinder half, where they contrast more strongly with the somewhat lighter ground color, a few small obscure blotches. Illicum orange in (a) off-white in (b), in both some evenly spaced purplish spots. Lure in (a) pale orange, a few minute specks of purple around point of attachment; in (b) whitish, several purple spots proximally and distally, three purple spots or imperfect annuli on each main process. Second and third spines in (a) medium brown; in (b) second whitish, third grey, faintly purplish. Soft dorsal in (a) medium brown in anterior one-third, becoming light brown behind; in (b) greyish with whitish bar below black-tipped rays. In (a) anal, pectoral, ventral mostly dark flesh-colour, in (b) mostly whitish or pale grey, with in each case some extension of dark body color on to upper surface of pectoral; in (a) caudal medium brown with a tinge of purple; in (b) greyish, some blackish spots on bases of upper five rays, most developed on uppermost, here involving more than half ray, two small black spots on lowermost ray.

Metrical patterns

(a) Outline in plan. The outline of the ventral surface is elegantly petaliform, subparabolic in front, reaching its maximum width shortly before the middle of the length, thereafter curving in to a continually narrowing caudal segment. Ten measurements of width have been made at equal intervals between snout tip and level of vent. These are fitted with a high degree of accuracy (R 0.998) by the following third degree polynomial, in which N is serial number of measurement, proceeding caudad:

$$W = 166.8 + 127.79N - 18.826N^2 + 0.6616N^3$$

predicted (measured) widths, *TLs*, 276(274), 354(354), 400(407), 419(416), 418(407), 398(398), 366(372), 323(327), 274(274), 224(221).

TABLE 5

Kuiterichthys furcipilis (Cuvier, 1817)

Parameters of rectified equations of logarithmic length of ray on logarithm of serial number of ray (anterior rays counted caudad, posterior cephalad), together with predicted and measured lengths. Two Tasmanian specimens, standard length (a) 113 mm, (b) 80 mm; ray dimensions as thousandths of standard length.

Fin	Specimen	Ray or spine set	Parameters		Predicted (measured) lengths, *TLs*	*t*
			Gradient	Intercept		
Dorsal	(a)	{1-8}	0.1522	2.0909	123(125),137(138),146(146),152(149),158(153), 162(158),166(165),169(179)	9.663***
		{13-8}	0.2448	2.0702	118(118),139(138),154(156),165(168),174(175), 182(179)	12.515***
Pectoral	(a)	{1-4}	0.2813	2.1036	129(125),154(158),173(175),188(183)	10.492*
		{10-5}	0.2094	2.0352	108(108),125(125),136(138),145(146),152(150), 158(158)	46.285**
	(b)	{1-4}	0.1887	2.1649	146(145),167(169),180(181),190(188)	13.117*
		{10-5}	0.2348	2.0992	125(126),148(149),163(163),174(175),183(185), 191(189)	36.313***
Ventral	(a)	{1-3}	0.2620	2.0512	113(113),135(135),150(150)	314.662*
		{5-3}	0.3129	2.0257	106(106),132(131),150(150)	48.647*
	(b)	{1-3}	0.3440	1.9610	91(91),116(117),133(133)	27.975*
		{5-3}	0.4073	1.9189	84(84),112(106),132(133)	7.262
Anal	(a)	{1-6}	0.3049	2.0486	112(114),139(134),156(157),171(168),183(186), 193(195)	19.463*
		{8-6}	0.6260	1.9850	197(197),149(146),190(195)	19.125*
	(b)	{1-5}	0.4049	1.9444	89(88),116(114),137(145),154(156),169(163)	10.016**
		{8-5}	0.2245	2.0744	162(163),152(151),139(139),119(119)	90.255***

(b) Anal rays. These comprise two sets in respect of length, the anterior, A {1-6} and the posterior, P = {8-6}, the sequence of the members of the set being that of increasing magnitude, in A caudad, in P cephalad; $A \cap P$; x = 6. In each set the logarithmic lengths of the rays are a linear function of the logarithms of their numbers. With counting caudad (N) in A, cephalad (N') in P the slope is in each case positive.

A. Log L = 0.3007 log N + 1.1362; t 58.091*** (r 0.9994); predicted (measured) lengths, *TLs*, 114(114), 140(140), 159(158), 173(175), 185(183), 195(196).

B. Log L = 0.6887 log N' + 1.9607; t 45.892* (r 0.9998); 91(92), 147(146), 195(196).

Similar linear loglog patterns of fin-ray length, with caudad and cephalad increase have been noted in these contributions as characterizing a number of diverse species.

(c) Pectoral rays. The pattern of log ray-length a linear function of log serial number of ray found in anal rays obtains also in pectoral rays, with A = {1-4}, P = {10-5}; however, here the elements of A are more numerous than those of P, and $A \cup P$. Left fin measured. The ray counted as the first is the uppermost, preaxial (Scott 1974).

A. Log L = 0.2813 log N + 2.1036; t 10.492** (r 0.991); predicted (measured) lengths, *TLs*, 129(125), 154(158), 173(175), 188(183).

P. Log L = 0.2094 log N' + 2.2035; t 37.792*** (r 0.9986); 108(108), 125(125), 136 (138), 145(146), 152(150), 158(158).

Loglog patterns for the pectoral involving two or more sets have been reported for various other species.

(d) Dorsal rays. The profile of the soft dorsal is in large part not far from rectilinear, with some visually insignificant decrease in altitude at either end. The pattern comprises an anterior ascending set, A = {1-8} and a posterior descending set, P = {8-13}; $A \cap P$; x = 8. In a loglog formulation the equations for the best straight lines are as below; N, N' as before:

A. Log L = 0.1522 log N + 2.0909; t 9.663*** (r 0.9969); predicted (measured) lengths, *TLs*, 123(125), 137(139), 146(146), 152(149), 158(158), 162(158), 166(165), 169(179).

P. Log L = 0.2448 log N' + 2.0702; t 12.513*** (r 0.997); 182(179), 174(175), 168 (165), 154(156), 139(138), 118(118).

(e) Ventral rays. In ventral fins with the most common formula, I, 5, the usual arrangement is that the fin elements increase in length from the first — by definition (Scott 1974) that furthest from the spine, or nearest midventral line of fish, postaxial — to the fourth, decreasing through the fifth to the spine; a loglog length-number relation has been found to be widespread. This pattern obtains here as far as relevant, rays increasing up to fourth. The logarithmic length-number formulation yields a straight line. Left fin measured.

Log L = 0.1945 log N + 1.9976; t 29.608** (r 0.998); predicted (measured) lengths, *TLs*, 99(100), 114(113), 128(125), 130(131).

(f) Caudal rays. The contour of the posterior border of the caudal, patently asymmetric, is found to be resolvable into three arcs, each a first degree function of log length and log serial number of ray. The graphed line is continuous, A {9-7} $\cap$ B = {7-4} $\cap$ C = {4-1}; A and B with positive slope, A the steeper, C with negative slope. With conventional treatment of uppermost ray as first (Scott 1974), the initial (left hand) point on the graph is that for the ninth (shortest) ray. Though the hind profile is asymmetric, the area, when formulated as above, presents a noteworthy aspect of symmetry, the area under the graph for A, 1.144, being significantly equal to the sum for B (0.729) and C (0.412); units common logarithms and thousandths of standard length. It is possibly adventitious that these three values are significantly linear (t 13.683*) on the logarithms of the first three integers.

A. Log L = 0.3871 log N' + 2.2239; t 19.239* (r 0.9987); predicted (measured) lengths, *TLs*, 167(167), 219(222), 262(254).

B. Log L = 0.1138 log N' + 2.3489; t 11.119** (r 0.984); 253(254), 261(259), 268(269), 274(274).

C. Log $L = -1.1624 \log N' + 3.3610$; t 7.956* (r −0.9698); 286(274), 239(258), 205 (203), 179(175).

(g) Dorsal fin origins. When the logarithmic lengths to the three separate elements of the dorsal are graphed against the logarithms of the first three natural numbers, they give a statistically straight line (r 0.991, t 23.055*). When the line is produced and the logarithm of the length to the first ray of the main dorsal is considered in relation to this extension, it is apparent it is appropriately sited on log 5 (r 0.9994, t 79.956***). The slope of the relevant equation for the four dorsal fin rays is log 1.7423, the intercept 1.4127; predicted (measured) values, *TLs*, 26(25), 87(92), 174(175), 427(411).

(h) Head length, length to vent, standard length. In a wide range of species it has been found the logarithms of these primary dimensions are collinear on the logarithms of three early natural numbers, the most commonly encountered sets being {1, 2, 3} and {1, 2, 4}. The present data are adequately specified by the latter set; length of head being treated as length to opercular margin.

Log $L = 0.7231 \log N + 2.5613$; t 37.630* (r 0.9996); predicted (measured) lengths, *TLs*, 364(367), 601(592), 992(1 000).

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RAISED BEACH DEPOSITS AND THE DISTRIBUTION OF STRUCTURAL LINEAMENTS ON MACQUARIE ISLAND

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(with two text-figures and seven plates)

ABSTRACT

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The distribution of previously-unmapped raised beaches on Macquarie Island makes it difficult to accept earlier interpretations of landform evolution. These raised beaches occur up to 270 m ASL, and in places previously thought to have been glaciated. The elevation of the beaches and the distribution and shape of many of the island's plateau lakes and structural lineaments would appear to be consistent with a history in which rapid uplift associated with block-faulting and other tectonic factors played a much more important role in landform evolution than has been recognised in the past.

INTRODUCTION

Some interest from time to time has attached to the geomorphic history of Macquarie Island but since the long period of field work there (late 1911-late 1913, see Mawson 1942: 277-298) by Blake (Mawson 1943) the number of people-hours spent researching this aspect of the island's evolution has been both spatially and chronologically scattered and rather sparse, being mainly limited to a few days during re-supply of the ANARE station established on the northern end of the island in 1948. Since then, results of comparatively extensive and detailed biological, geological and related work (e.g. see Betts 1980, 1981a, 1981b, 1981c, 1981d) together with some results from work in oceanography and marine geology (e.g. Hayes 1972, Kennett *et al.* 1974, specifically pages 121-3) form a background against which ideas about the landform evolution of Macquarie Island can be reassessed. In particular it is worth awaiting the opportunity to test conflicting theories about the nature and extent of Quaternary glaciation (e.g. Mawson 1943, Colhoun & Goede, 1974, Peterson 1975, Orlov 1977, and Loffler & Sullivan 1980). Remote and isolated, amid a large expanse of the Southern Ocean, Macquarie Island is a lonely representative of the few terrestrial environments which are so important to many Southern Ocean species, the origin and dispersal of which will have been influenced by Quaternary events. The history of these events must be assembled from evidence on the islands and on the sea floor.

The bathymetry of the ocean south of the Tasman Sea (e.g. Cullen 1969, Hayes & Talwani 1972, fig.1), suggests that Macquarie Island is situated on the emergent crestal sector of a ridge (The Macquarie Ridge) which has been formed by the interaction of the Pacific and Indian tectonic plates. The northernmost part of the ridge is coterminous with New Zealand from whence it runs south to join the Indian-Pacific mid-ocean ridge system on a part of the Antarctic Ridge (e.g. see Varne *et al.* 1969, fig. 1) which continues through the Balleny Islands to the Ross Sea.

The island is formed of brecciated and pillowed basalts together with dolerites, gabbros and serpentinized peridotites (Varne & Rubenach 1972). This ophiolitic association has been recognised as relatively pristine mid-Tertiary oceanic lithosphere created at the Antarctic mid-oceanic ridge (Griffin & Varne 1980, Griffin 1982). These have been uplifted during activity along the seismically-active Macquarie Ridge to form a plateau some 35 km long by five km wide standing 300-400 m above sea level.

Geological fault-zones are common, the island consisting of a number of fault-bounded blocks, probably on all scales (Varne & Rubenach 1972, p.251). Earthquakes are shallow and first-motion analyses imply that the ridge is associated with normal, thrust and strike-slip faulting (Hayes & Talwani 1972).

Such a geological setting suggests that overall uplift, and the distribution of lineaments (mainly fault-lines) will be very important influences upon landform evolution. Such a notion has guided our recent field work on Macquarie Island (R.L. Nov. 1976 to Nov. 1977, Nov. 1979 to Nov. 1980; J.A.P. Nov. 1980, Nov. 1982) which, instead of concentrating upon searching for evidence of glaciation, has involved extending observations made by earlier workers of features that can be related to structural and tectonic control of geomorphology. Thus, this paper is predominantly about the distribution of raised beaches and of lineaments.

RAISED BEACHES

Previous Discoveries

Mawson (1943) noted that "As viewed from the sea, the skyline of the land is generally uniform as to be strongly suggestive of former planation, probably marine planation prior to [... what he envisaged as ...] the period of glaciation." (plate 1)

He also noted a coastal raised beach predominantly along the northern part of the west coast of the island from the isthmus southwards to Bauer Bay with intermittent narrow strips on the east coast. Evidence for this beach is backed up by the occurrence of several sea caves and arches five to ten m above sea level (Aurora and Eagle caves, plate 2) and a surprising amount of mostly overgrown flotsam and evidence of shipwrecks up to 300 m from the waters edge. An abundance of sea stacks can also be seen between Handspike Point and Soucek Bay on the western coastal plain with many others scattered along other sections of the coast.

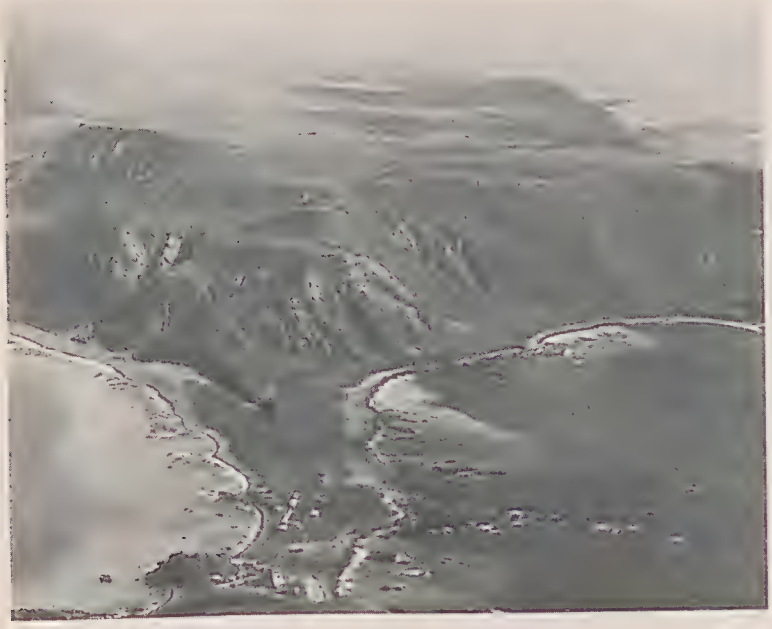

Plate 1 The plateau surface in the region of Scoble and Island Lakes. It is in this northern part of the plateau that the majority of the beaches discovered so far are preserved. Several terraces can be seen on the plateau edge in the left centre foreground. The 260-270 m and the 180-210 m beaches occur on the plateau.

Mawson also noted that there exists at Bauer Bay, deposits capped by a layer of boulders which he stated probably belong to the time of the raised beach. The boulder beds are approximately 15 m above sea level and the sand below contains King penguin and diving petrel bones.

Orlov (1977) in the company of one of the authors (R.L.) discovered beach pebbles overlain by 3-4 m of peat on Wireless Hill in 1976 (Beach 1, fig. 1 N). The remnants of this beach stand 100 m above present sea level. Orlov also remarked on numerous terraces at various heights between 28 and 240 m ASL which he thought were of marine origin. The presence of the higher terraces calls into question some previous accounts of the distribution of glacial landforms in that beach pebbles would probably be redistributed and terraces smoothed out if overridden by ice.

Although the raised beach pebbles on the terraces described here indicate a marine origin for them, it is other (periglacial) terrace types that have been mapped to date (e.g. Taylor 1955, Loffler *et al.* 1983). Clearly the distribution of the beach pebbles and their terraces should also be mapped.

Distribution of Raised Beaches and Related Terraces

Between the present sea level and the hills of the island plateau, several clearly-defined beach terraces have been located. These terraces have been mapped (fig. 1) and many of them are thought to have been of marine origin. The most clearly-defined of these levels are found 260-270 m, 180-210 m, 150 m, 90-100m, and 10-15 m above sea level. On all these terraces beach deposits varying from coarse sand or cobbles to large rounded boulders have been found. The remainder include terraces with exposed bedrock that may carry shingle, as do present-day wave-cut platforms, but which on the older raised terraces is buried by debris from the back-slope. These features are not mapped as comprehensively as those with rounded beach pebbles.

The results of the mapping are presented in the folding maps (figs 1 and 2) and described below. Terraces at heights between about 270 m and 1-3 m are mapped. Because of the extensive block-faulting referred to above, the conveniently-clustered terrace height-ranges should not be taken as indicating contemporaneity between separated terraces. The ranges, nevertheless form convenient categories within which the occurrences are described and discussed below. Some locations are reported with reference to spot heights marked on the National Mapping Division map (1:50 000) Macquarie Island (first edition, Nov. 1971).

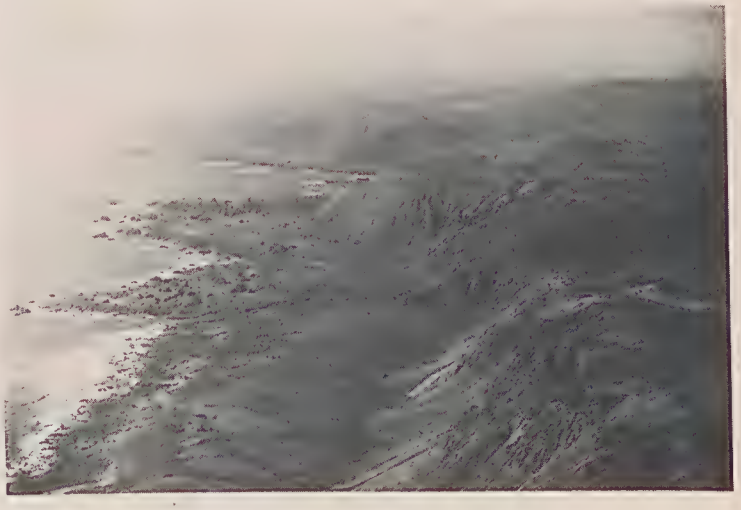

Plate 2 - The west coast of Macquarie Island showing many of the abandoned sea stacks which occur on the 8-9 m beach below the plateau surface. Aurora Caves looking north.

Plate 3 - Beach cobbles at about 260 m ASL, NNE of Scoble Lake.

1. 260-270 m Beaches

Scoble Lake Beach

During 1980 an area of well-rounded boulders (plate 3) of considerable size (30-40 cm) was found on the well-worn path 200 m NNE of Scoble Lake on the northern section of the plateau (Beach 2, fig. 1 N). On tracing this raised beach which intersected the path at a NNW/SSE line, areas of boulders were found extending for 1000 m across the face of the hill on the slopes of North Mountain at a height of 260-270 m ASL. The boulders were unbedded with other beach deposits varying from coarse sand to small pebbles. A shallow excavation revealed the depth of the deposits to be in excess of 0.25 m and there appeared to be two definite horizons, one 10 m above the other. Heights were measured by aneroid altimeter and were therefore not particularly accurate but checks with trig. points suggest an accuracy of ±20 m. These beach deposits are not obvious topographically but occupy a gently-sloping hillside with only one area of clearly-defined notching forming a low cliff-line along the face of North Mountain. At the northwestern extremity, the slope is much more gentle and the deposits are widely scattered over the hillside with no clearly-defined margin.

A search of the northern slope of North Mountain revealed the remnants of the beach on the other side of what must have been a small island consisting of North Mountain, Mt Elder and Mt Blair when Macquarie Island first rose above sea level as a result of tectonic uplift (Beach 3, fig. 1 N).

To the south, other mountains would have probably been exposed, but no definite beaches have yet been found at a level as high as those on North Mountain.

A search of the northern third of the island, north of the Sandy Bay/Bauer Bay line revealed a large number of terraces particularly where the slopes became quite gentle, or on flats such as ridge tops. On some of these, beach deposits were found. It became clear early in the investigations that only on these gently-sloping areas would clear evidence of beaches be found. On the rocky and steep hillsides, platforms and beach deposits still in place would be masked by talus.

2. 180-210 m Beaches

Island Lake, Scoble Lake Terraces

Several flat-topped terraces, 190 m ASL and facing NW can be seen between Scoble and Island Lakes. Scattered round boulders 0.2 to 0.3 m in length (see plate 3) and clearly beach-worn (Beach 4, fig. 1 N) form the surface. The terraces are flat-topped, unvegetated (except by clumps of moss) and 50-100 m wide. They form two distinct lobes. This area however is somewhat confusing since a few of the boulders have, on their lower surfaces, striae which may be glacial on origin. It is suggested that such boulders may have originated at a higher level (perhaps on the 260-270 m beach) on the south side of Boot Hill and have been carried down to their present site by a small glacier. These terraces may therefore mark the limit of glaciation in the Scoble Lake/Island Lake Basin. A diligent search of the valley above the terraces up to Boot Hill failed to reveal any sign of the occasional pebble which would have inevitably been dropped *en route*. Nor are there any beach pebbles below the terraces to indicate that they were deposited during a retreat of the glacier from lower altitude. This area warrants further investigation.

Stony Creek and Flat Creek Beaches

On the northern side of Stony Creek valley, at a height of 180 m ASL, a beach extends for 100 m along the hillside in an area which has been eroded of its peat cover (Beach 5, fig. 1 N). The exposure is approximately 20 m in width. Many of the larger boulders, which range up to 0.35 m in diameter, have moved down slope. The vertical thickness of the deposit is therefore difficult to estimate; it is probably two to three metres.

In contrast, on the southern side of Flat Creek at 190 m ASL, where slopes are much gentler, a similar deposit rests, comparatively unmoved, with regolith above and below fashioned into solifluction terraces (Beach 6, fig. 1 N).

Tulloch Lake

Several beach pebbles were found at 170 m near the SW corner of Tulloch Lake and similar terraces to those on the south side of Flat Creek were found on the ridge between Flat and Stony Creek near spot height 178. Exposed rock outcrops suggest the survival of an old wave-cut platform. No pebbles were found.

Other localities

At roughly the same height above sea level as those described above, several other localities support the case for a beach at 180-210 m ASL in this area.

Island Lake.- On the walking track about one km SSW of Island Lake beach pebbles up to 0.15 m in diameter were found.

Douglas Bay.- On the plateau edge above Douglas Bay 150 m south of spot height 243, beach pebbles up to 0.1-0.2 m in diameter were found.

Prion Lake.- Several beach pebbles were found at 180 m at the NE end of the lake near the walking track.

Skua Lake.- On the plateau edge between Sellick and Soucek Bays about one km north of Skua Lake, and also in the valley of the river draining the lake between Mt Eitel and Mt Ifould and running into Skua Lake, numerous beach pebbles can be found on the cliff edge (Beach 8, fig. 1 N).

Major Lake.- On the northwestern (windward) shore of Major Lake, between the edge of the lake and the plateau cliffs, a bank of fine beach shingle, with boulders up to 0.4 m in diameter, has been found (Beach 9, fig. 1 N). Major Lake faces west, directly into the prevailing winds. That shingle is found on the windward but not on the lee shores of this and other lakes illustrates the difference in rates of shingle formation on lake and sea shores on Macquarie Island. Pebbles subject to lake shore processes on Macquarie Island are not yet modified beyond sub-angularity. In each case examined to date the presence of well-rounded cobbles on lake shores can be attributed to a raised (marine) beach deposit there or nearby.

In addition, a number of terraces can be seen at various parts of the island at approximately the same heights as the above-mentioned beaches. At 180 m elevation on the slopes above Gadget Gully (Heartbreak Hill) a well-defined terrace can be traced north towards Perseverance Bluff. Several clearly-defined terraces can also be seen on the walking track between Island Lake and Bauer Bay, particularly near a small un-named lake one km south of spot height 219. Others can be seen in the Finch Creek, Green Gorge and Pyramid Peak areas.

On either side of Jessie Niccol Creek, Waterfall Bay, an extensive area of terraces between 180-200 m ASL has been mapped but no definite evidence to indicate marine origin was found during one brief search.

3. 150 m Beach

The 200 m contour defined the lower edge of the plateau over the majority of Macquarie Island. Only in a few areas, mainly the major river valleys, does gently-sloping or flat-lying ground occur below this height.

Between the plateau edge and the coastal plain the coastal cliffs are steep, and eroding so rapidly that raised-beached deposits would be redistributed and/or buried. Thus scope for preservation of readily-identifiable *in situ* beach deposits here is limited.

A beach, however, has been found consisting of sand with cobbles up to 0.1 m in diameter on the summit of the windswept ridge between Stony Creek and Flat Creek at a height of 150 m ASL; one of the few areas of gently-sloping ground below 200 m. The beach material covers a large area on the summit of the ridge (Beach 7, fig. 1 N). It is essentially flat-lying and well-exposed between small banks of moss and grass. An excavation down to 0.2 m revealed mainly rounded shingle between 50 and 200 mm in length with some angular fragments of frost-shattered rock. Below this beach lies a series of peat-covered terraces extending northwards down to Gentoo Flat. These terraces occur at approximately ten m intervals between 100 and 140 m above sea level. Two others can be seen at 50 and 80 m respectively.

Further evidence of a 150 m beach occurs in the form of well-developed terraces at Sawyer Creek, Jessie Niccol Creek, Lusitania Creek and in Caroline Cove Creek below Mt Haswell.

4. 100 m Beach

The 100 m level forms a distinct shelf-like platform on both sides of the deeply-incised bed of Stony Creek near Bauer Bay. Rock is exposed immediately below the lip of the southern bank terrace, capped in parts by a thin layer of peat. This area may therefore have been a wave-cut platform.

The plateau edge on the side of Wireless Hill has been eroded to expose the raised beach (plate 4) mentioned previously (Orlov 1977). This beach is overlain by 3-4 m of peat which has been found to contain marine littoral diatoms and pollen from seashore plants (Selkirk *et al.* 1983). A near-basal sample of this peat (about four m below the surface of the peat) indicates a minimum age of about 5500 years for the beach (see Selkirk *et al.* 1983, table 1 and fig. 6). Samples taken at 394 m contained phytoliths, diatoms, chysomonad cysts and abundant grass pollen all of which indicate a sequence of deposition in a seashore environment (Selkirk *et al.* 1983).

Plate 4 - Beach pebbles at 100 m elevation on the western edge of the plateau-top of Wireless Hill. Photograph: J.J. Scott.

Several pebbles were also found on a terrace approximately 400 m north of Green Gorge at a height of 110 m ASL and may have resulted from the same sea level. Several other terraces have been mapped 1.5 km NW of Green Gorge and also in Sawyers Creek 5 km SW of Green Gorge.

5. 8-9.1 m Beach

The evidence for the existence of a 9 m beach has been discussed by Colhoun & Goede (1973). This terrace is exposed in three areas, Bauer Bay, Green Gorge and Finch Creek (Sandy Bay) and consists of several metres of interbedded deposits containing fossil King penguin bones capped by sand and cobble beach-deposits. The penguin bones have been dated to a maximum of 6100 ±120 years B.P. (Gak - 643) and the peats above the cobbles to an age of approximately 2000 years B.P.

Terraces of similar height to these beaches are widespread through the island (plate 2).

6. 1-3 m Beaches

The isthmus surface is covered by a layer of shingle surmounted by several abandoned sea stacks. Excavations have revealed rock platform at approximately 3 m ASL in the area of the ANARE station. Two distinct wave-cut platforms can be seen on Garden Bay rock on the north side of Garden Bay. One is exposed below a rock face only about a metre above present normal high tide. The other is approximately 2 m ASL and is exposed to seaward of the lower beach and on the eastern top of the rock point. Both of these wave-cut platforms can also be sighted at various parts of the coast—notably the east coast, the lower platform (1 km approx.) can be seen on the rocks at the north side of Sandy Bay (where it is often covered by heavy swells) and also in Secluded Beach and Goat Bay.

The higher platform is well developed at the northern end of Secluded Bay and also at Green Gorge approximately 300 m north of the hut.

Raised Beaches and Landscape Evolution

Raised beaches represent net changes in sea level and may, in the form of isostatic marine limits, be important indicators of local ice margin fluctuations. Particularly-well-dated flights of raised beaches or terraces have been used to construct eustatic sea level curves once allowance has been made for tectonic effects (e.g. Chappell 1983). Alternatively, if the terrace sequence is but sparsely dated such information as exists may be used to infer uplift rates after correction factors from the eustatic curves have been applied. Thus in southern Fiordland, New Zealand, an average uplift rate of 4.3 mm/yr for the last 240 000 years has been inferred (Bishop 1983) and further north, in southern Westland a rate of 5 mm/yr for the last 9700 years is reported (Cooper & Bishop 1979). Macquarie Island is on the same plate boundary as these localities. Selkirk *et al.* have inferred a maximum possible uplift rate that would average 14 mm/yr for the Wireless Hill area for the last 5500 years. During the last two thousand years or so lower rates appear to have prevailed south of the isthmus, as indicated by the dating of basal peats on marine terraces on both sides of the island close to sea level (e.g. 1.5-4.5 m/1000 years - see Colhoun & Goede 1973). However late Quaternary uplift rates need not have been constant, nor evenly distributed. The rocks of Macquarie Island are part of the mid-Tertiary oceanic lithosphere (Griffin & Varne 1980) and their uplift to elevations higher than that of any other part of the Macquarie Ridge suggests that uplift rates for the island must be amongst the highest for the ridge as a whole. Clearly, as for other parts of this same plate-boundary collision zone, raised terraces such as those described above bespeak rates of tectonic activity commensurate with a high degree of endogenic control of landscape evolution. It is argued in the next section that this control is evident in the landscape.

STRUCTURAL GEOMORPHOLOGY

Seismic activity on Macquarie Island is frequent though generally minor. Historically, earthquakes have been documented since the first recorded visitors arrived at Macquarie Island in 1810 (see Cumpston 1968, pp.5, 37). Bellinghausen recorded earthquakes when lying at anchor offshore (*op. cit.*, p.44). Cumpston (1968) recorded earthquake reports by several sealing expeditions. Mawson (1943, pp.64-65) listed ten earthquakes of varying intensity (some quite severe) during the A.A.E. party's sojourn during 1911-1913, and several very severe tremors were felt by a sealing gang from the vessel *Betsy* between October 1915 and May 1916.

In recent times a strong earthquake (Richter scale 6.7 - Ledingham 1978) in 1977 and a similar one in 1980 (Ledingham 1981) caused widespread rockfalls and mud slides around the island. The epicentres of both were shallow and 20-40 km to the west of the island. Many aftershocks were even closer - some 200-300 being recorded in a few days after the 1980 shock.

Such activity prompted closer examination of the few good-quality air photographs available of the plateau, and it became evident that the structural geology, and in particular the distribution of faults, may have played a much greater role in the formation of geomorphological features of Macquarie Island plateau than previously thought. Prominent

lineaments were mapped (figs 2 N and 2 S) and can be seen to coincide with many of the main topographic trends. The patterns evident from these maps prompt an alternative interpretation of many of the features formerly attributed to glaciation. For instance, many of the lakes and straight valleys mapped as glacial troughs are fault-controlled in such a way as to preclude glaciation as a necessary agent in their formation (e.g. see plate 5).

Plate 5 - A typical faulted lake basin on the south coast of Macquarie Island near Hurd Point. Several other faults can be seen in the area.

Scoble Lake

The 260-270 m marine terrace lies at its closest point, some 200 m from Scoble Lake and some 20-30 m above it, extending through into the col between North Mountain and Boot Hill above the lake. Many of the smaller surrounding lakes are on the lower terraces, between 220-256 m, which also may be of marine origin. Scoble Lake, however, is bounded on its southern side by a rock wall which forms part of a lineament running west into Half Moon Bay and to the east into Nuggets Creek forming the col between Boot Hill and North Mountain.

Soundings taken in the lake revealed that it is much deeper on the rock wall side (5 m) which presumably forms a natural dam. This type of lake is quite common on the island. For example, a lake immediately south of Mt Ainsworth (near Hurd Pt, plate 5) is bounded on one side by a clearly-defined lineament; one of a number in this area (plate 5 and fig. 2 S) A minimum age for the oldest deposits beneath the floor of this lake is 8700 ± 220 B.P. (Wk-349) (Salas 1983).

South of a line between Sandy Bay and Bauer Bay the island consists of fault-bounded blocks of volcanic rocks (mainly pillow lavas). Several major, and a large number of minor faults have formed depressions in which many of the island's lakes lie. The fault lines are evident on air photographs and have been mapped as lineaments.

Square Lake

The distribution of lineaments in this area suggests that Square Lake is fault-dammed on its western side. The wall is now breached by a small stream and the basin so formed, is filled almost completely by silt. Before breaching the fault wall, the lake has obviously overflowed to the northeast into Finch Creek. A small corrie glacier may have existed on the southern face of the hill (210 m) immediately to the north. The lineament can be seen on the western flank of this hill extending south across the headwaters of

Flat Creek where what are probably fault lines (at least three) mark sunken road-like depressions at right angles to the line of the valley.

Tulloch Lake

Further east, two parallel lineaments trending NE towards Finch Creek, outline the depression in which Tulloch Lake now lies.

Prion Lake

Prion Lake, Macquarie's deepest lake, also lies in a depression bounded by lineaments that strike in the same direction as the Tulloch Lake faults (NE). On the NW bank, which is very steep, the main lineament is paralleled by two others. All three can be traced NW to Mt Tulloch. The lineament forming the SE bank can be traced SW along the flank of Mt Eitel eventually forming the back wall of the valley which drains SW into Skua Lake.

Nearing the walking track to the NE of the lake, several beach pebbles were found. These pebbles were up to 60 mm in diameter and are unlikely to have been deposited by skuas or ANARE personnel. A beach, therefore, may have existed in this area; perhaps *in situ* or on the flanks of Mt Eitel whence the pebbles were transported by mass wasting (probably periglacial) to their present site.

Barker Lake - 1 km east of Mt Ifould

This lake is also bounded by lineaments on both sides with a series of terrace-like steps formed by parallel fault-lines on the flanks of Mt Ifould and Mt Eitel.

An upthrusted fault-block, described by Colhoun & Goede (1974, p.12) as a low-level kame terrace, follows the line of Red River. The continuation of this same lineament, to the southwest past Mt Ifould, was mapped by the same authors as a melt-water channel. Close inspection reveals that this lineament can be traced over the col to the south into the next valley. For this to be a melt-water channel it would, because it rises over a col, have to be subglacial and therefore beneath a relatively thick glacier which would probably have left a more obvious legacy than is evident.

Brothers Fault-line

Brothers Fault-line has been used as a convenient name for one of the most impressive and clearly defined lineaments on the island, apart from those that actually determine the general outline of the coast and plateau edge (plates 6 and 7).

From Nuggets Point to Sandy Bay, the Brothers Fault-line probably defines the edge of the coastal rock platform. South of Sandy Bay it strikes inland between Brothers Point and Mt Tulloch causing the formation of a coastal ridge as far south as Green Gorge. It continues south from Green Gorge along the western flank of Sawyer valley, again forming a flat-topped coastal plateau at a height of about 200-250 m. After crossing Jessie Niccol Creek, it can be traced in the coastal cliffs south of Waterfall Bay. The same fault, or another parallel to it, forms the rock-bar at the mouth of Lusitania Creek and continues southwest of Mt Aurora, Mt Jeffryes and across the head of Whiskey Creek finally terminating in the sea at Hurd Point. An ESE dip is suggested by the displacement of its line to the east where it is close to sea level.

The northern section of this lineament, Brothers Point and Green Gorge stands out very clearly on air photographs (plate 6). The upward displacement of the eastern side is clearly visible on the coastal cliffs south of Brothers Point where a rampart-like ridge runs parallel to the plateau edge, but some 50 m below it for approximately 300 m. Scree-covered slopes have developed from fault-breccias shed from the uplifted (eastern) side of the fault and may be traced as far south as Red River. These unusual screes also occur between Green Gorge and Pyramid Peak. The structural control of topography in the area is reflected in the drainage pattern: eastward draining streams have been dammed by upthrust rock thresholds. The lakes thus formed have been silted and their outflows have subsequently breached the threshold to flow eastward into the sea (plate 6).

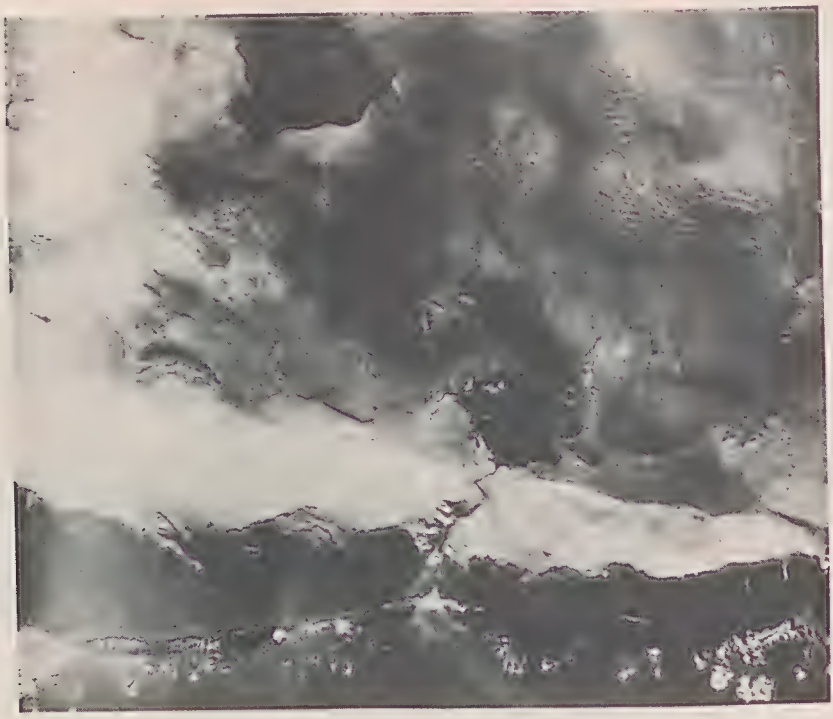

Plate 6 - The prominent lineament of the Brothers Fault-line showing breccia screes (lighter shading) and the small fault-dammed lake which has breached the upthrusted coastal ridge (lower). Vertical air photograph, Macquarie Natmap run 6, CAS8470 No.66, 6/2/76 (ANARE negative number 31999).

Among other lakes dammed by such faulting, some, including those drained by Red River and Lusitania Creek, have been drained because of incision but a small remnant of the Green Gorge Lake remains.

Doubts about a glacial origin for Major Lake have been published (Peterson 1975). This is further confirmed by the existence of raised beach pebbles on the 50-100 m wide lip of the plateau edge between the lake and the sea. The distribution of lineaments in this area suggests that faulting accounts for lake-forming drainage disorganisation. Some of the lineaments are more persistent than others. For instance, the lineament forming the depression in which the small triangular lake at the NE corner of Major Lake lies, extends south through the col between Mt Gwyn and Mt Martin and the line of it can be traced down into Lusitania Creek.

The pattern of lineaments around the lake south of Mt Blake further support tectonic origin as the most likely explanation for most lakes in this area.

Steep cliffs on the Mt Blake side of Flynn Lake and on the Mt Waite side of Lake Gratitude suggest that these lakes too, were dammed as the result of block or step-faulting.

LANDSCAPE EVOLUTION

The presence of raised beaches and of structural lineaments is to be expected in tectonically-active locations such as the boundary zone between tectonic plates. The distribution pattern of the lineaments indicates the nature of structural control upon the landscape, and casts doubt upon some landscape interpretations invoking extensive glaciation.

Plate 7 - Brothers Fault-line clearly showing the upthrust eastern coastal wedge (right) and a small lake basin partially filled with sediment and bog. This was interpreted earlier as a melt-water channel.

Such interpretations are based on the identification of glacial landforms, mainly on the basis of morphology and, at least to date, without any detailed stratigraphic or petrographic evidence. Maps published previously, depict generalised patterns of glacier flow as indicated on fig. 2. It is evident that glacial landforms have been mapped in areas where we have identified raised beaches. Many of the "deepened" glacial lakes and glacial melt-water channels previously mapped are as easily explained by recourse to evidence of widespread faulting resulting from the tectonic instability of the island.

Glacial histories of other tectonically-active areas with summits at or near the Pleistocene snowline may have been modulated or inhibited by this tectonic factor (e.g. see Verstappen 1959). We suggest, in short, that the elevation of Macquarie Island above sea level has been a late Quaternary event. Juxtaposition of the various geomorphic interpretations represented in figs 1 and 2 reveals distributions, that, if true, would require some far from simple rationalisations. There are also some incompatible distributions. For instance the raised beaches east and northeast of Scoble Lake (e.g. plate 3) occur in an area which is mapped as glaciated by both Colhoun & Goede (1974) and Loffler & Sullivan (1980). It is unlikely that unconsolidated deposits of beach cobbles on the terraces would have survived glaciation without redistribution and/or burial.

The implications of this juxtaposition of interpretations include the following:

1. Perhaps the glacial landforms mapped by previous workers are examples of "convergence of form". In other words they possess similarities to some undoubtedly glacial landforms in other and more thoroughly documented parts of the world, but on Macquarie Island have been formed without glaciers. Landform descriptions reminiscent of those published by advocates of a glacial origin for the geomorphology of Macquarie Island occur in papers on the physiography of the "Australian Alps". The glacial interpreta-

tions attached to many of these descriptions have been refuted (e.g. see Galloway 1963, Peterson 1971).

2. Perhaps the uplift of most or all of Macquarie Island to elevations close to glacial-stage snow lines post-dates the last glacial stage.
3. The interpretations here advanced, and also those challenged, would be tested if the age and environmental history of the lakes could be studied in more detail than hitherto.
4. The debate about the evolution of landforms on Macquarie Island would be greatly advanced if all interested workers had access to a set of good quality aerial photographs, side-looking radar and other remotely-sensed images covering the whole island.

SUMMARY AND FUTURE WORK

The elevation of the beaches and the distribution and shape of many of the island's plateau lakes and structural lineaments would appear to be consistent with a history in which rapid uplift associated with block-faulting and other tectonic factors played a much more important role in landform evolution than was previously recognised.

The debate about the age of the terrestrial environments would be much advanced if dateable materials could be unearthed from the raised terraces. Diachronous lake formation as implied by the structural as opposed to the glacial origin could be tested by collecting lake-bottom cores and comparing dated lacustrine stratigraphies. Detailed appraisal of the raised shorelines would include study of the possible influence of glaciation and of their preservation and/or modification in the face of periglacial activity (Griffin 1980, Loffler *et al.* 1983, Peterson *et al.* 1983). Study of the age and altitudinal distribution of raised beaches may give an indication of rates and nature (possibly differential?) of uplift. Thus there is the opportunity for integrating the study of geomorphology and tectonics for the mutual benefit of advancing debate in both of these aspects of geology.

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The Director of the National Parks and Wildlife Service, Hobart gave permission for research groups from Monash University to visit the island in 1979, 1980 and 1982, at which times transport and logistical support was provided by the Antarctic Division, Department of Science. Dr B.J. Griffin (Electron-Optical Centre, University of Adelaide) kindly commented on the manuscript before final preparation for submission to the editor. We are also grateful to Dr E.A. Colhoun for his comments. The folding maps were drawn by Mr Gary Swinton and prepared and printed under the direction of Mr J.E. Missen in the Geography Department, Monash University.

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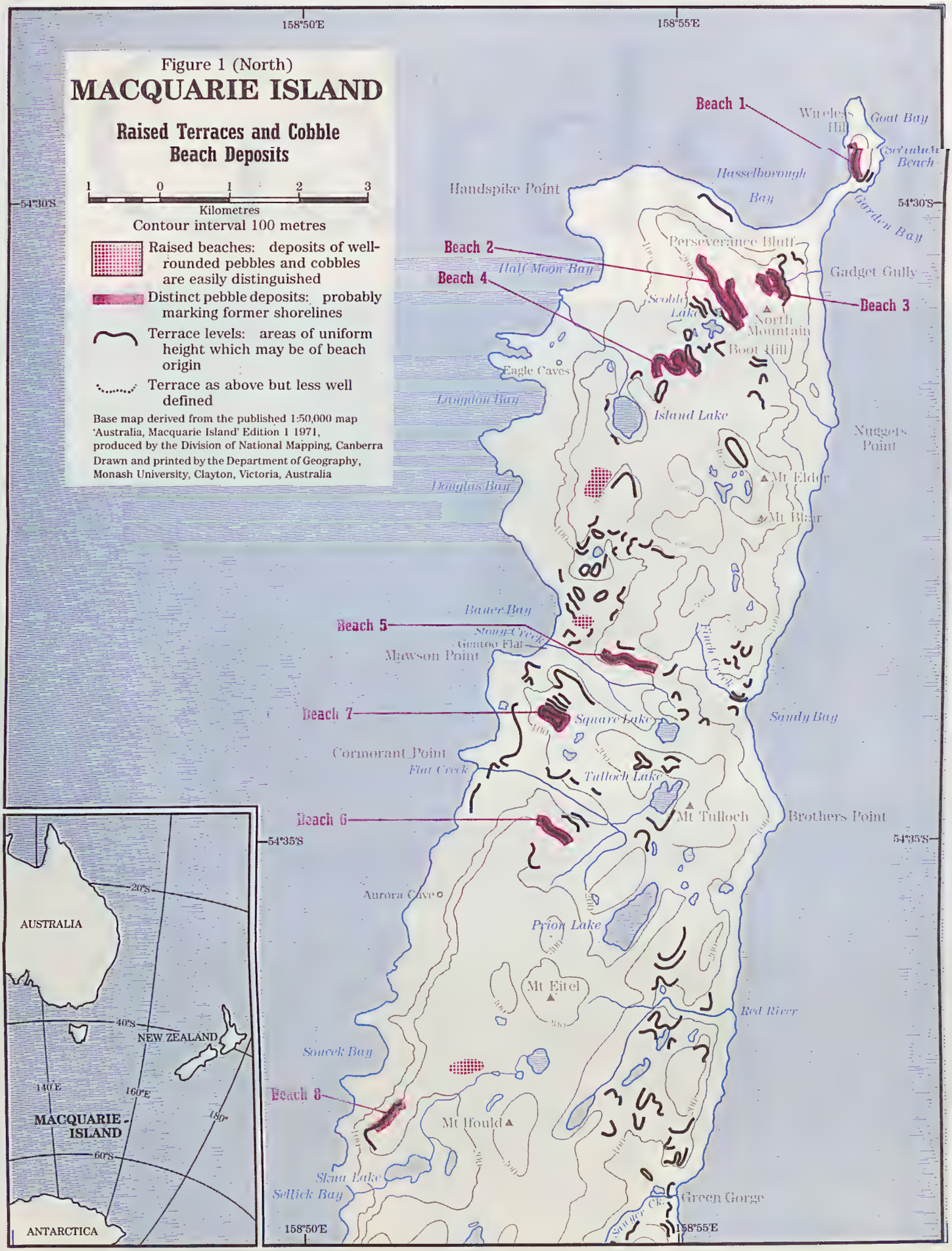
Figure 1 (North)
MACQUARIE ISLAND
Raised Terraces and Cobble Beach Deposits
1 0 1 2 3
Kilometres
Contour interval 100 metres
Raised beaches: deposits of well-rounded pebbles and cobbles are easily distinguished
Distinct pebble deposits: probably marking former shorelines
Terrace levels: areas of uniform height which may be of beach origin
Terrace as above but less well defined
Base map derived from the published 1:50,000 map 'Australia, Macquarie Island' Edition 1 1971, produced by the Division of National Mapping, Canberra
Drawn and printed by the Department of Geography, Monash University, Clayton, Victoria, Australia
158°50'E
158°55'E
54°30'S
54°35'S
Beach 1
Beach 2
Beach 3
Beach 4
Beach 5
Beach 6
Beach 7
Beach 8
Wireless Hill
Goat Bay
Hasselborough Bay
Handspike Point
Garden Bay
Perseverance Bluff
Half Moon Bay
Gadget Gully
Scoble Lake
North Mountain
Boot Hill
Eagle Caves
Langdon Bay
Island Lake
Nuggets Point
Mt Elder
Mt Blair
Douglas Bay
Bauer Bay
Stony Creek
Gentoo Flat
Mawson Point
Finch Creek
Square Lake
Sandy Bay
Cormorant Point
Flat Creek
Tulloch Lake
Mt Tulloch
Brothers Point
Aurora Cave
Prion Lake
Mt Eitel
Red River
Soucek Bay
Mt Ifould
Skua Lake
Sellick Bay
Green Gorge
Sawyer Ck.
AUSTRALIA
NEW ZEALAND
MACQUARIE ISLAND
ANTARCTICA
20°S
40°S
60°S
140°E
160°E
180°

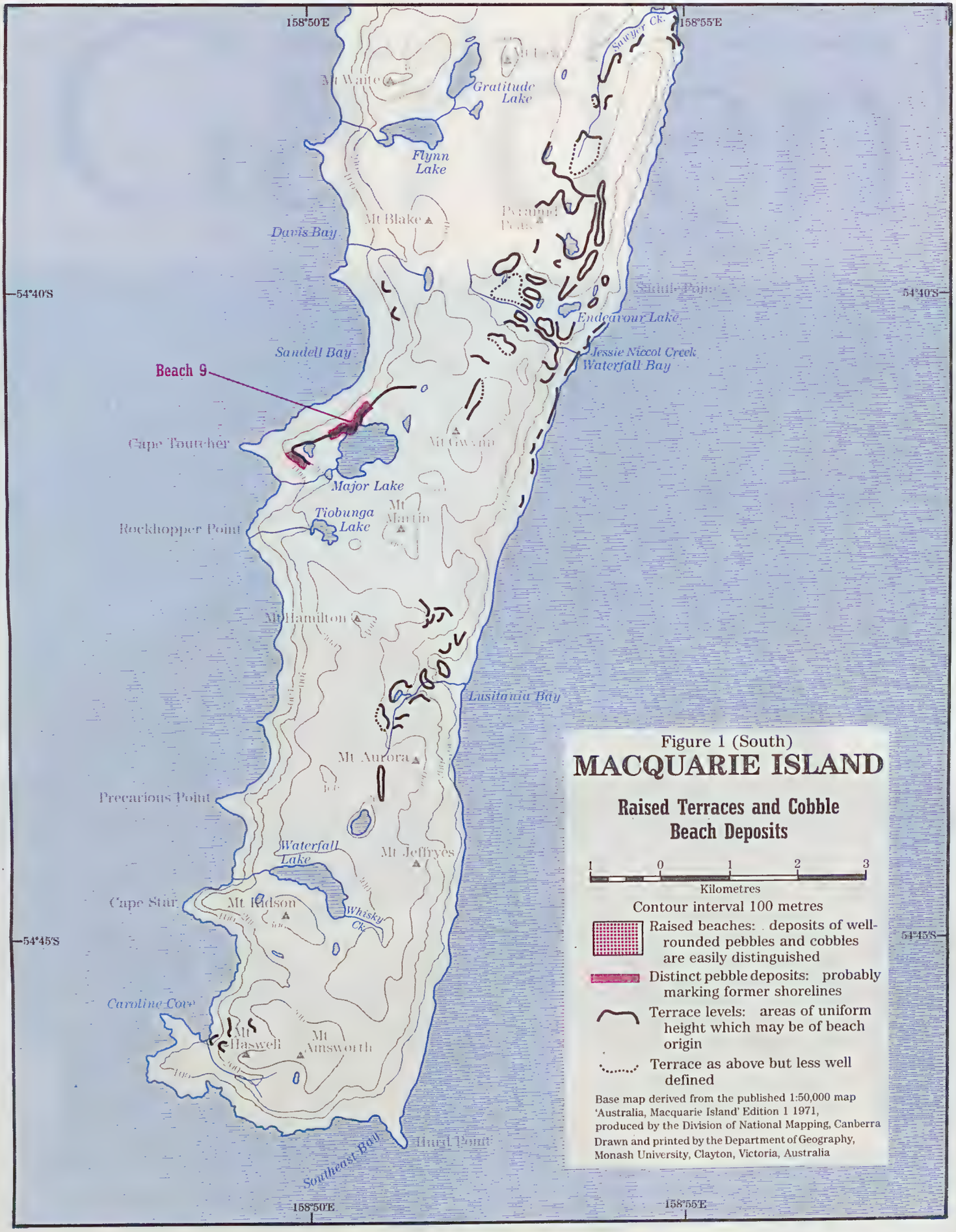

Figure 1 (South)

MACQUARIE ISLAND

Raised Terraces and Cobble Beach Deposits

Base map derived from the published 1:50,000 map 'Australia, Macquarie Island' Edition 1 1971, produced by the Division of National Mapping, Canberra

Drawn and printed by the Department of Geography, Monash University, Clayton, Victoria, Australia

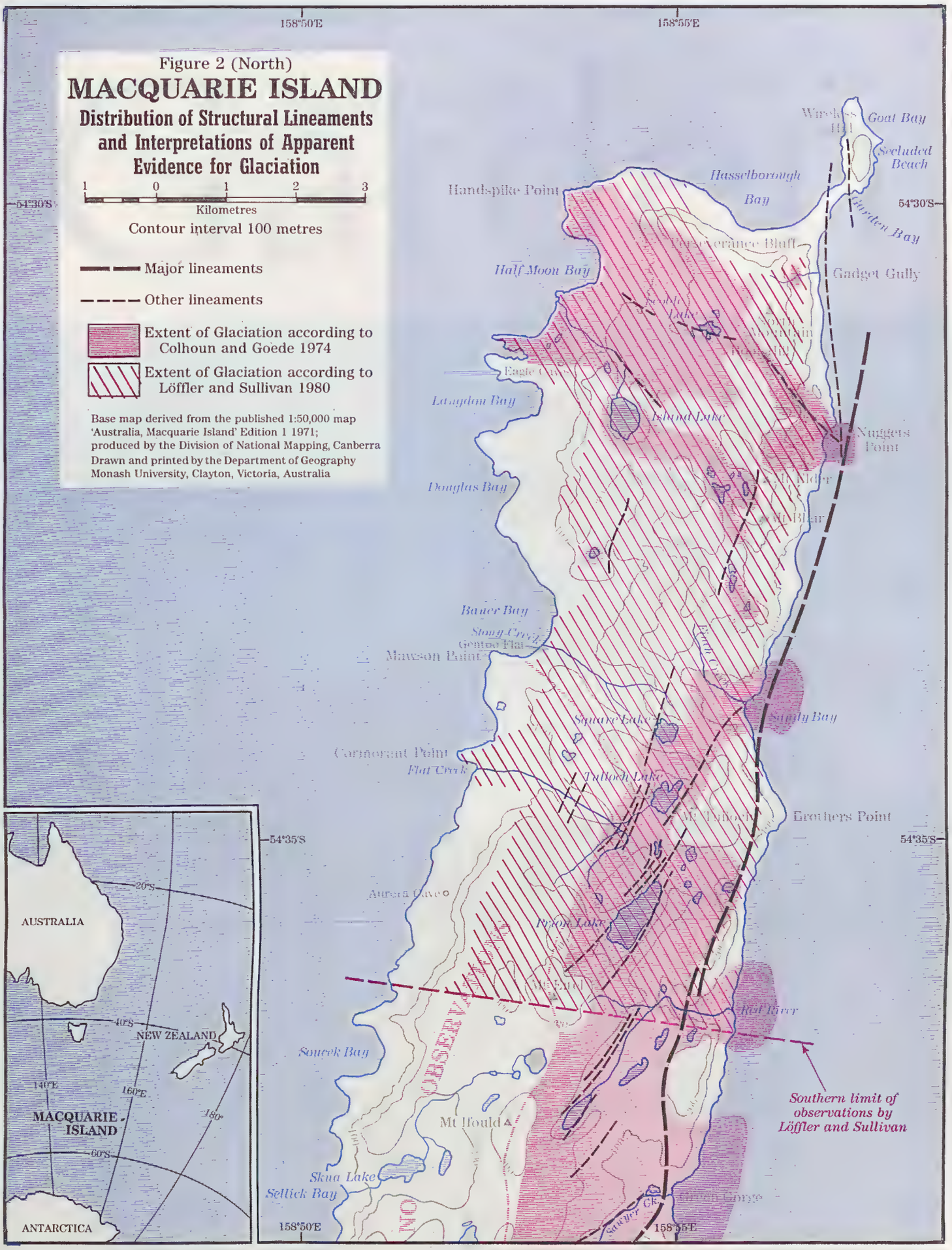
Figure 2 (North)
MACQUARIE ISLAND
Distribution of Structural Lineaments and Interpretations of Apparent Evidence for Glaciation
1 0 1 2 3
Kilometres
Contour interval 100 metres
Major lineaments
Other lineaments
Extent of Glaciation according to Colhoun and Goede 1974
Extent of Glaciation according to Löffler and Sullivan 1980
Base map derived from the published 1:50,000 map 'Australia, Macquarie Island' Edition 1 1971; produced by the Division of National Mapping, Canberra
Drawn and printed by the Department of Geography Monash University, Clayton, Victoria, Australia
158°50'E
158°55'E
54°30'S
54°35'S
Goat Bay
Secluded Beach
Hasselborough Bay
Handspike Point
Garden Bay
Perseverance Bluff
Half Moon Bay
Gadget Gully
Eagle Caves
Langdon Bay
Island Lake
Nuggets Point
Douglas Bay
Mt Elder
Mt Blair
Bauer Bay
Stony Creek
Gentoo Flat
Mawson Point
Finch Creek
Square Lake
Sandy Bay
Cormorant Point
Flat Creek
Tulloch Lake
Mt Tulloch
Brothers Point
Aurora Cave
Prion Lake
Mt Eitel
Red River
Soucek Bay
OBSERVATION
Mt Ifould
Skua Lake
Sellick Bay
Sawyer Ck
Green Gorge
Southern limit of observations by Löffler and Sullivan
AUSTRALIA
NEW ZEALAND
MACQUARIE ISLAND
ANTARCTICA
20°S
40°S
60°S
140°E
160°E
180°

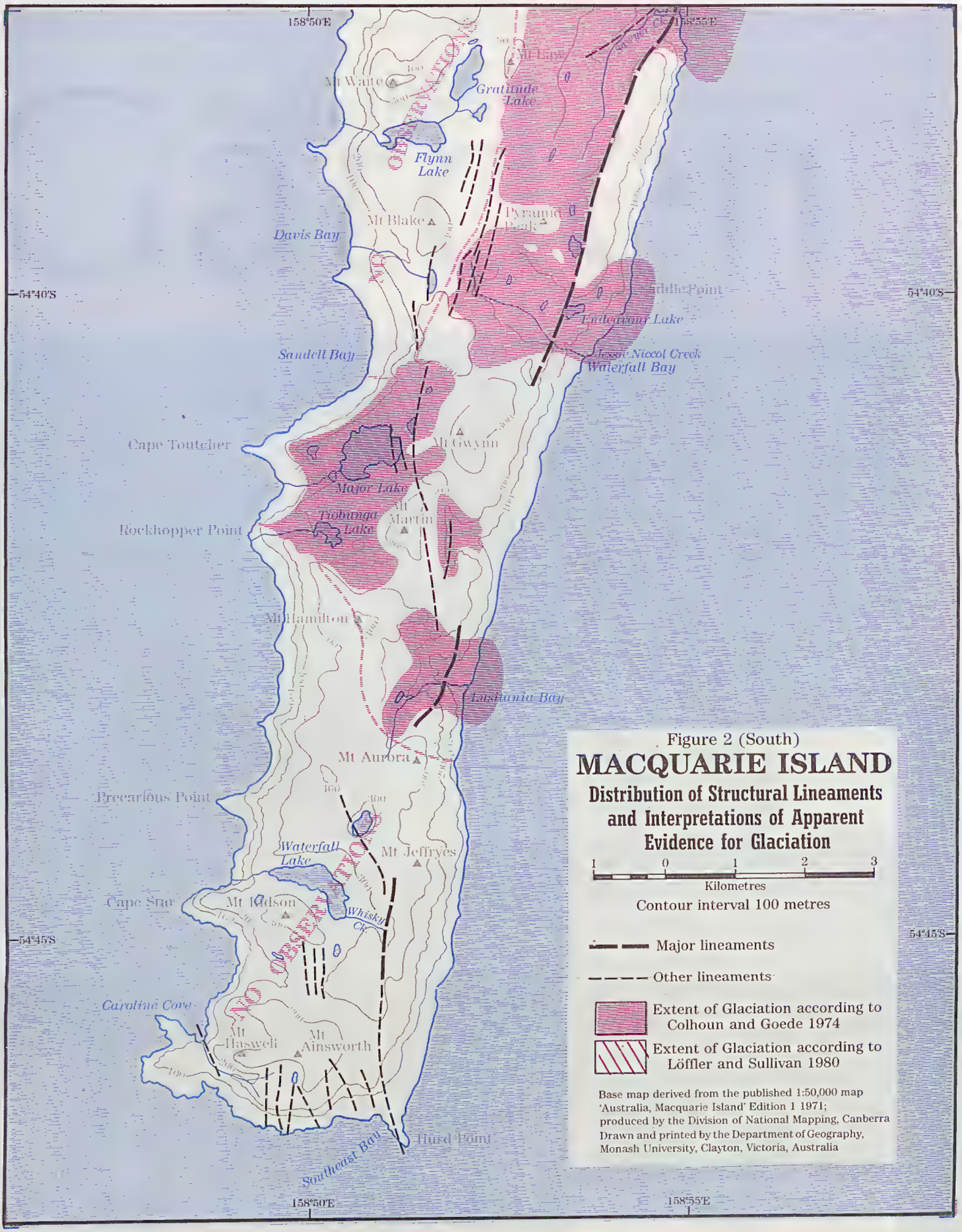

Figure 2 (South)

MACQUARIE ISLAND

Distribution of Structural Lineaments and Interpretations of Apparent Evidence for Glaciation

1 0 1 2 3

Kilometres

Contour interval 100 metres

Major lineaments

Other lineaments

Extent of Glaciation according to Colhoun and Goede 1974

Extent of Glaciation according to Löffler and Sullivan 1980

Base map derived from the published 1:50,000 map 'Australia, Macquarie Island' Edition 1 1971; produced by the Division of National Mapping, Canberra
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